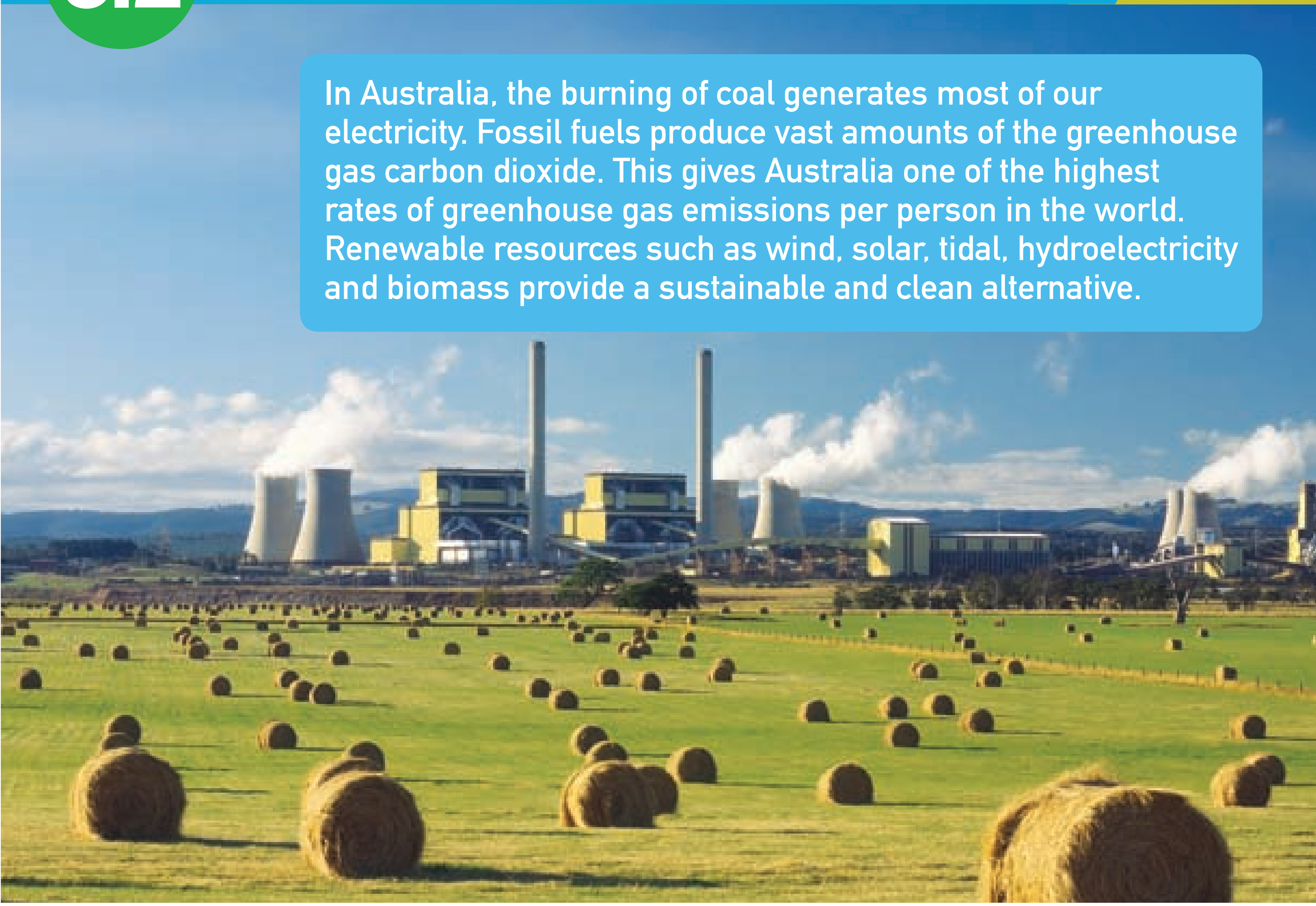
3.2 Energy sources

In Australia, the burning of coal generates most of our electricity. Fossil fuels produce vast amounts of the greenhouse gas carbon dioxide. This gives Australia one of the highest rates of greenhouse gas emissions per person in the world. Renewable resources such as wind, solar, tidal, hydroelectricity and biomass provide a sustainable and clean alternative.



Energy demand

Early humans had basic energy needs. Without electricity and fossil fuels, their energy needs were met from sunlight and from burning fuels like wood and dried animal manure. Energy demands have risen dramatically in recent times. This can be seen in Figure 3.2.1. Appliances and gadgets such as televisions, iPods, home entertainment units, gaming consoles and computers require a lot of energy to manufacture. They also require ongoing energy to use. Climate-controlled living rooms and the convenience of car and air travel come at an energy cost too. Table 3.2.1 shows that, relative to many parts of the world, Australia and other Western societies such as the United States and Europe consume large amounts of energy.

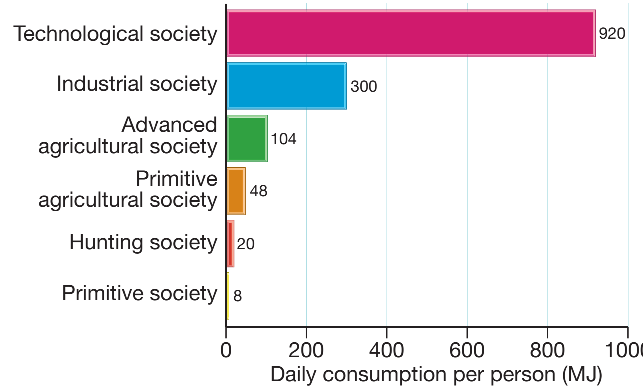


Figure 3.2.1 Comparing the energy needs of primitive cave dwellers with the energy used in today's society highlights the massive increase in energy consumption of recent times.

Table 3.2.1 Energy use per person (GJ) in various countries

Country	Yearly energy use per person (GJ) [1 GJ = 1000 million J]
Australia	240
Canada	348
China	48
Egypt	32
El Salvador	29
Ethiopia	12
Greece	113
Italy	131
Pakistan	19
United Kingdom	164
United States	327

Non-renewable energy sources

Oil, coal, gas and nuclear are energy sources that cannot be replaced. Energy sources such as these are called **non-renewable** energy sources. Oil, coal, gas and their products (such as petrol and diesel) are called **fossil fuels**.

Some 300 million years ago, the dead remains of prehistoric animals and plants were covered by layers of mud, sand and dirt. Pressure and heat below the Earth's surface gradually transformed these remains into the different fossil fuels than can be found today. The original source of energy for these fuels was the sunlight absorbed by the prehistoric plants, and stored in their remains or in the remains of the animals that ate the plants. When burnt, fossil fuels release large amounts of energy but also large amounts of the **greenhouse gas** carbon dioxide. This increased concentration of carbon dioxide in the atmosphere is thought to contribute to climate change.

Nuclear fuels, such as uranium and plutonium, are other non-renewable sources of energy that are used to generate electricity. Small amounts of these fuels can produce large amounts of energy in a chain reaction in a process called nuclear fission. This chain reaction is carefully controlled in a nuclear power plant. The heat created is used to generate electricity. Nuclear power plants do not produce greenhouse gas emissions and are used as the main power source in many countries. However, the process of nuclear fission used in the plants produces wastes that remain radioactive for thousands of years. Safe storage of these wastes remains a problem.

Figure 3.2.2 shows that more than 80% of the world's energy supply is obtained from oil, coal and gas. These are all non-renewable fossil fuels. Australia has plentiful supplies of coal and it is relatively cheap. Major energy sources used in Australia include:

- black and brown coal, to produce steam used to generate most of our electricity
- petrol to power most of our cars, with some using LPG (liquefied petroleum gas, another fossil fuel)
- diesel to power most trucks and some trains
- natural gas for much of our cooking, central heating and hot water services.

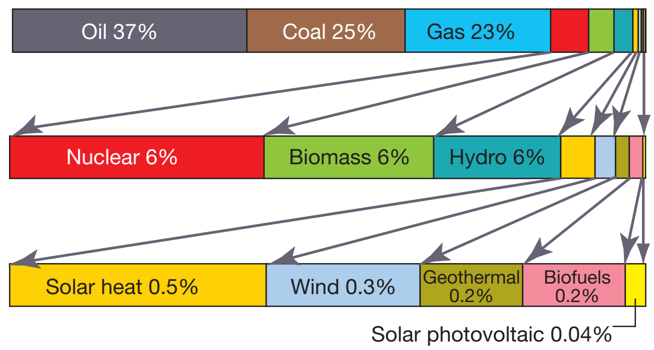


Figure 3.2.2 This chart shows where the world's energy comes from. The second and third rows show detail that cannot be seen in the eight smallest bands of the original (top) graphic.

SciFile

Brown isn't green

Brown coal releases a third more carbon dioxide than the same amount of black coal for only half the heat. Trials are being conducted to develop 'clean coal' technologies to capture and store carbon dioxide emissions from power plants such as Loy Yang. Loy Yang power station, in the Latrobe Valley in Victoria, consumes up to 60 000 tonnes of brown coal per day to supply about one-third of Victoria's energy. Most environmentalists argue that it should be shut down.

Renewable energy sources

Renewable sources of energy can be used over and over again. To build an energy supply for the future and to limit greenhouse gas emissions there is a need to switch from fossil fuels to renewable sources. Power companies offer households the option to buy all their electricity or some of it from an accredited green power provider. This means that by paying slightly more you can buy electricity that has been sourced from renewable energy. Key sources of renewable energy are:

- moving water
- Sun
- wind
- heat within the Earth
- oceans and rivers
- biomass.

Hydroelectricity

Gravity causes things to fall, including water. Water falling from a higher to a lower level (such as from the dam shown in Figure 3.2.3) can be used to turn turbines and generate electricity. This form of electricity is called **hydroelectricity**. The Snowy Mountains hydroelectric scheme is the largest hydroelectric power scheme in Australia. It consists of 16 dams, 7 power stations and over 145 km of tunnels. Hydroelectric schemes are a renewable energy resource. However, large-scale projects change the way rivers flow and alter the environment.

Figure 3.2.3 The energy of falling water is used to turn turbines that generate electricity in a hydroelectric power station.

Biomass

Biomass describes energy that is obtained from materials such as dead plants, plant matter, or animals and their wastes. These materials contain stored energy captured from the Sun. This energy can be released for use in many different ways:

- Heat energy is released when products such as wood or dried manure are burnt.
- When organic wastes such as fruit peelings and grass clippings are put into landfill, they decompose, producing methane and carbon dioxide gases. This gas mixture, called **biogas**, can be collected from landfill sites and the methane gas then used as a fuel.
- Biogas can be produced from human sewage and animal wastes. Production is conducted within tanks fitted with digesters that encourage breakdown of the waste.
- Agricultural crops such as corn (shown in Figure 3.2.4) and sugarcane can be fermented to produce ethanol, which is used as a liquid fuel. Agricultural wastes such as rice husks can also be used to produce ethanol.
- Vegetable oils from plant seeds such as oil palm, sunflower, canola, soybean, sesame and linseed can be converted into biodiesel fuel.
- Algae are harvested to produce biodiesel fuel.

3.3
1 p90

SciFile

A sugar rush

Brazil produces vast crops of sugarcane and uses some to produce ethanol. Most new cars are designed to run on ethanol. This change has lessened Brazil's dependence on oil – its cars are essentially solar powered!

Figure 3.2.4 Corn ethanol is produced in this processing plant in Iowa, USA. The corn grain shown here is a waste product of the process and is sold as animal feed.

Solar energy

Light from the Sun is a valuable renewable resource. It can be used in many ways to provide energy.

- The direction a house faces (its orientation) can help to reduce the need for additional heating and cooling. Using interior materials that absorb sunlight through the day and then release heat at night also helps.
- Sunlight can be used to heat rooftop solar panels to provide households with hot water.
- **Solar cells** (such as that shown in Figure 3.2.5) use materials called semiconductors to convert sunlight directly into electricity. Rooftop solar cells can provide household electricity, and any extra electricity generated can be fed back into the electricity grid. Solar cells are expensive to produce, but their generating capacity is increasing each year. This is reducing the cost of producing electricity using solar cells.
- A solar pond consists of a large volume of water to which salt is added. The pond is lined with black plastic. Sunlight heats water at the base of the pond, and the heat can be used to generate electricity.
- Large-scale solar energy systems, such as that shown in Figure 3.2.6 on page 84, rely upon vast arrays of mirrors to concentrate sunlight. These devices can be used to generate electricity with no greenhouse gas emissions.

Figure 3.2.5 Solar cells are useful for providing energy to small-scale devices such as calculators or garden lighting and for providing electricity in remote areas. The solar cell in this picture is on top of the phone booth.

INQUIRY science 4 fun

Using the Sun

What energy changes occur with a solar cell?

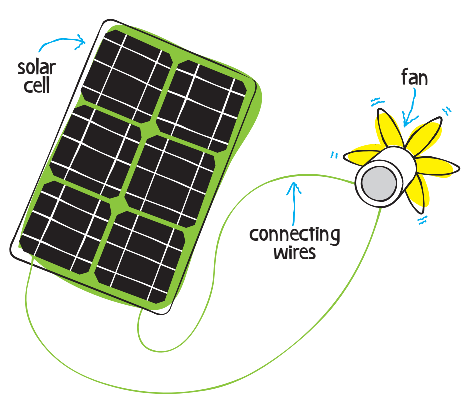
No

Collect this …

- solar cell
- connecting wires
- electric motor with a fan

Do this …

1. Use the connecting wires to connect the solar cell to the electric motor.
2. Stand outside (preferably on a sunny day) with the solar cell facing the Sun.



Record this …

Describe what happened.

Explain why you think this happened.

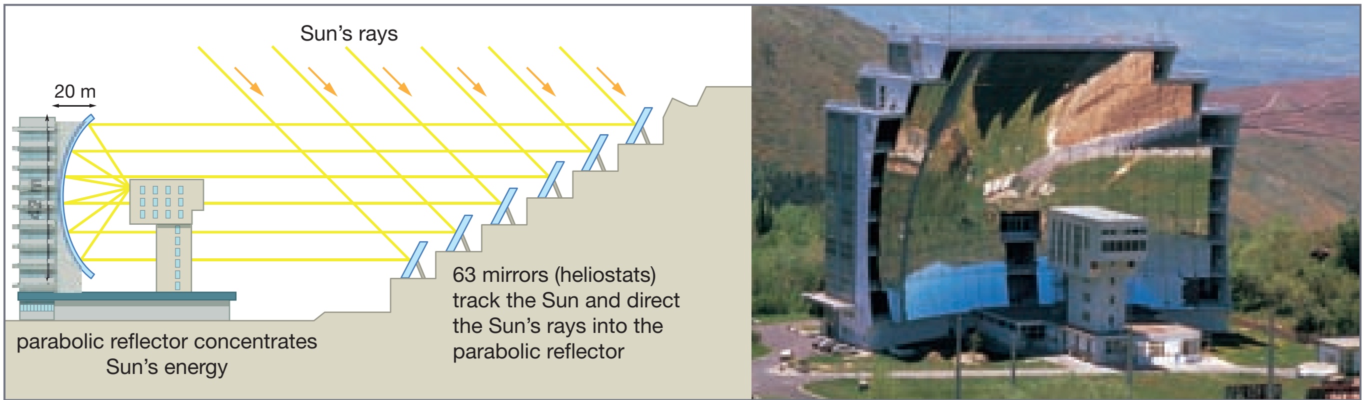


Figure 3.2.6 A solar furnace can produce temperatures up to 3800°C. Solar furnaces can be used to generate electricity or to conduct experiments on materials at extreme temperatures.

Wind energy

Wind energy has been used for centuries and windmills have long been used in Australia to pump water. Wind turbines are like large windmills but are used to generate electricity. Wind farms are located in windy places. You can see a wind farm in Figure 3.2.7.

2 p91

Figure 3.2.7 Wind energy generates no greenhouse gas emissions. Nearby residents may object to wind farms because they do produce noise and occasionally birds may be injured by the turbines as they spin.

Energy from the ocean

There are a number of different techniques that harness energy from the ocean. Although these techniques are generally expensive to establish, they offer a clean energy source once they are operating. An **oscillating wave column** (shown in Figure 3.2.8) and a **tidal barrage** (shown in Figure 3.2.9) are two examples.

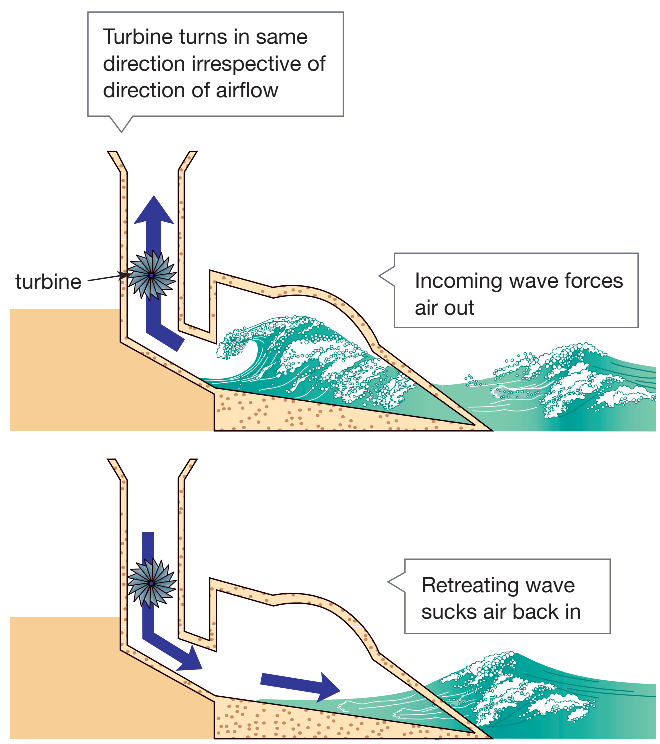


Figure 3.2.8 The oscillating wave column relies on the pressure of the waves to suck air in and out around a turbine to generate electricity.

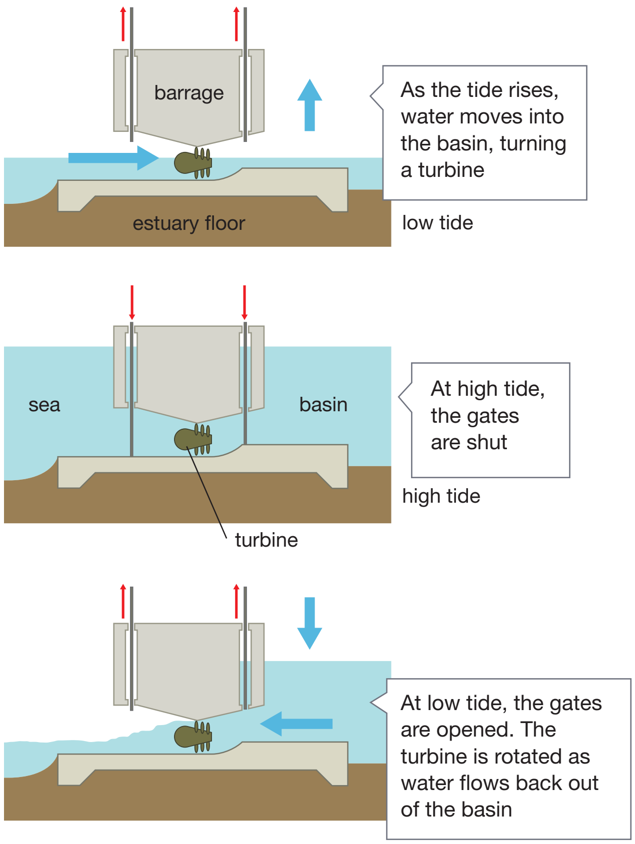


Figure 3.2.9 At low tide, the gates of the tidal barrage open to allow water to fill a basin. These gates are shut at high tide. When the tide is low, the gates are reopened and the pressure of water rushing out is used to generate electricity.

Geothermal energy

Beneath the Earth's crust lies molten magma (melted rock). In Iceland, Japan and New Zealand, this heat lies fairly close to the surface and heated water may burst from the surface as a natural hot spring or geyser like the one shown in Figure 3.2.10. This heated water can be used directly to generate electricity. Another way to use **geothermal energy** is to pump water underground through drilled channels and circulate it through the hot rock. The water is heated by the rock and is used to generate electricity when it returns to the surface. This is shown in Figure 3.2.11. A geothermal power plant has been built at Birdsville, in Queensland, and plants are being developed in South Australia. Geothermal power plants tap into a plentiful natural energy source. However, they are limited to specific areas and can result in pollutant gases escaping from below the Earth's surface.

Figure 3.2.10 This steam is produced by geothermally heated water in Iceland.

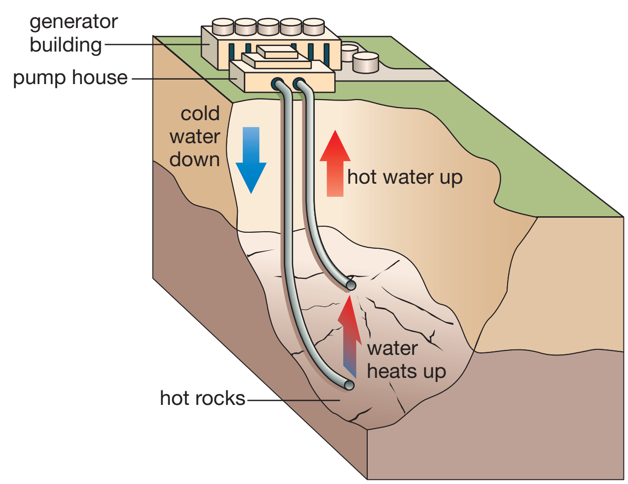
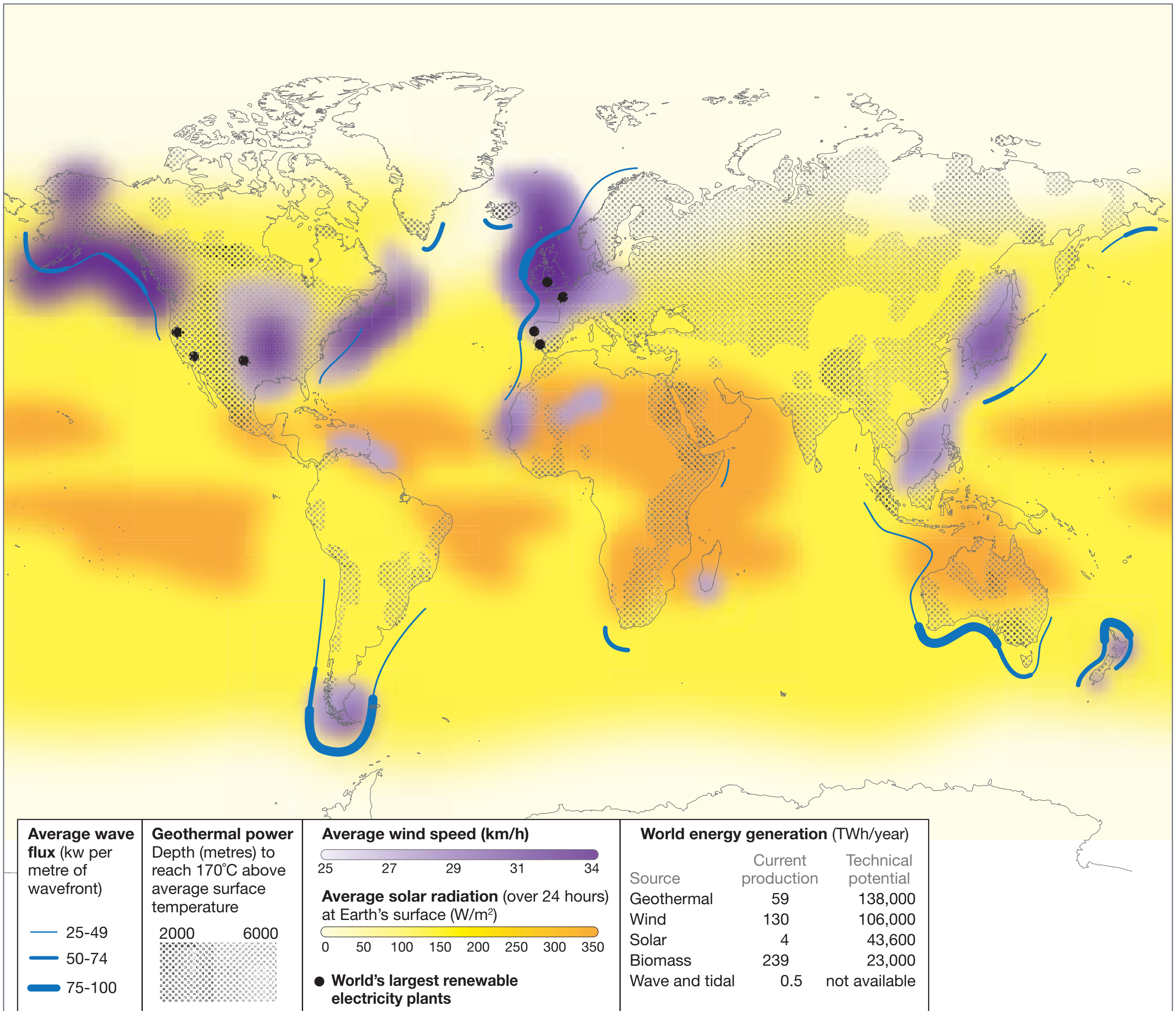


Figure 3.2.11 A geothermal power plant relies upon cold water being pumped below the surface where it is naturally heated over hot rocks and then returns to the surface.

The big picture

A major problem associated with many renewable energy sources is that their output is not continuous. Wind turbines, solar systems and wave generators rely upon the wind blowing, sunlight being present and waves crashing. Better methods need to be developed to store energy when demand is low so it can be used when demand rises. Figure 3.2.2 on page 81 shows that solar energy, geothermal energy and wind energy provide a small fraction of the world energy supply at present. A better approach is to utilise a number of renewable sources of energy. Figure 3.2.12 on page 86 illustrates the enormous potential of renewable energy sources worldwide and highlights the regions best suited to each type.



World energy generation (TWh/year)

Source	Current production	Technical potential
Geothermal	59	138,000
Wind	130	106,000
Solar	4	43,600
Biomass	239	23,000
Wave and tidal	0.5	not available

Figure 3.2.12 The depth of yellow shading indicates the average solar radiation reaching the surface of the Earth. The purple zones indicate regions of high wind speed. The blue lines indicate high tidal activity.

Energy conservation

Reducing the energy we use will ease demands on resources and will minimise greenhouse gas emissions. Here are some ways you can make a difference:

1. Switch off TVs and computers when they are not needed.
2. Walk, ride a bike or catch public transport instead of driving.
3. Use blinds and fans in summer instead of airconditioners.
4. Insulate yourself in winter by wearing a jumper and using blankets or thicker doonas.
5. Drink tap water rather than bottled water.
6. Use cloth bags or a backpack for shopping. Avoid purchasing products with lots of packaging.
7. Reduce the amount you buy, reuse what you have before throwing it away, and recycle goods you no longer need.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Umeme Kwa Wote—Energy for all

Figure 3.2.13 In 2008, an experimental program was launched in Kenya that enabled people to recharge a solar-powered lamp such as this one in an energy hub.

About one quarter of the world's population do not have access to an electricity supply.

For many generations, fishermen living by the shores of Lake Victoria, in Eastern Africa, have relied upon kerosene lamps to light their homes and catch fish at night. Kerosene is readily available in remote areas and easy to buy in small quantities. However, it is expensive and highly flammable, and at times kerosene leaks into the lake, adding to its pollution. It is estimated that the burning of kerosene in lamps around the lake produces about 50 000 tonnes of carbon dioxide gas every year.

In April 2008, a lighting company built the first 'energy hub', on the banks of Lake Victoria. Its name is *Umeme Kwa Wote*, Swahili for *energy for all*. It is an energy station consisting of 42 solar panels installed on its roof. These panels convert the tropical sunlight into a clean supply of electricity. Three hubs have been built in Kenya and one in Uganda, with hopes to build another 100 energy hubs in Africa and 20 in Asia.

For a small fee, locals can use this electricity to recharge energy-efficient fluorescent lamps for use on their boats and in their homes. They can also take a rechargeable battery from the energy hub to power fishing lamps. A typical lamp is shown in Figure 3.2.14. It relies on an 11 W globe and is watertight and dust resistant. Costs are much lower than the equivalent costs for kerosene, the light from the lamps is brighter, it carries no health risks, and no greenhouse gases are produced in the process.

The battery can also be used to charge small appliances such as mobile phones and radios. When the batteries are flat, they are brought back to the hub for recharging and are swapped for a charged battery.

The woman shown in Figure 3.2.13 is carrying a lantern with an internal rechargeable battery. This lantern operates for 8 hours, or even longer when switched to a lower power LED light designed to provide enough light to read a book at night.

Figure 3.2.14 These fishermen are dragging their net into the waters of Lake Victoria. They hope to catch sardines attracted by the light source.

3.4

3.2 Unit review

Remembering

1 a **State** one key advantage associated with the use of fossil fuels.
  b **State** two key disadvantages associated with fossil fuel use.

2 **State** one advantage and one disadvantage associated with the use of nuclear fuel.

3 **List** the three sources of energy that supply the majority of the world's needs.

4 **List** five types of seeds that can be used to produce biodiesel fuel.

5 **Recall** another name for a solar cell.

6 **State** the fraction of the world's population that has no access to electricity.

Understanding

7 **Explain** the difference between renewable and non-renewable sources of energy, giving an example of each type.

8 **Outline** how fossil fuels are formed.

9 **Define** the term *biomass*.

10 **Describe** five different ways sunlight can be used as an energy source.

Applying

11 a **State** the average energy use in gigajoules (GJ) of an Australian over a year.
  b **Calculate** this value in joules (J).

12 Each situation below describes different energy changes. **Use** the options in the box below to **identify** which type of energy is being used in each case.

hydroelectricity
oscillating wave column
biomass
fossil fuel
tidal barrage
solar energy
geothermal energy
wind energy

  a Wood is burnt in a camp oven to boil a kettle.
  b Natural gas is used to heat a saucepan of pasta on a stove.
  c Falling water turns turbines that generate electricity.
  d Sunlight falling on a photovoltaic cell is directly converted into electricity.
  e Turbines rotate as air flows through them and this is used to generate electricity.
  f A turbine rotates in one direction and then the other as moving water sucks air past its blades.
  g Water flows rapidly over a turbine, which is used to generate electricity.
  h Water pumped below the surface of the Earth is heated and used to generate electricity.

13 Refer to Figure 3.2.12 to answer the following questions.
  a **State** the current production of electricity from solar sources (in TWh/yr).
  b **State** how much electricity could potentially be produced from solar sources (in TWh/yr).
  c **Propose** three regions of the world that would be best suited to utilising:
    i solar energy
    ii wind energy
    iii ocean energy
    iv geothermal energy.
  d Looking at Australia on this illustration, **propose** which renewable resource you think would be best suited to development in the state or territory that you live in.

14 **Use** Figure 3.2.2 on page 81 to **state** the percentage of world energy consumption supplied by:
  a oil
  b solar photovoltaic energy
  c nuclear energy.

Analysing

15 **Compare** the key advantages and disadvantages between two renewable energy sources, such as solar, wind, tidal, geothermal or hydroelectric energy production.

Evaluating

16 a **Assess** whether nuclear energy is a renewable or non-renewable energy source.

b **Justify** your answer.

17 **Propose** why it is recommended that you switch off appliances at the power source.

18 **Propose** what is meant by the term *green energy*.

19 Consider the suggestions to help households conserve energy use.

a **Identify** one of these that you could easily act on this week.

b **Propose** your own personal list of 10 ways that you could save energy.

Creating

20 Australia has plenty of brown and black coal. It is relatively easily mined and relatively cheap.

a **Construct** an argument for or against the use of coal as an energy resource.

b **Use** the arguments of the class to run a debate on whether coal should continue to be used as a major source of electrical energy in Australia.

Inquiring

1 Find articles in the newspaper, magazines, on TV current affairs shows or on the internet regarding energy use and energy resources. Assess the arguments presented in each article and use your knowledge of renewable and non-renewable resources to summarise the claims made in them.

2 a Summarise the major sources of energy used in the state or territory in which you live. Survey a number of people about the energy that they use and compare whether this is in agreement with your research.

b Investigate the energy sources used by two countries other than Australia. Compare their energy sources with those used in Australia.

c Research and report upon an aspect of renewable energy technology that is being developed by Australian scientists. For example, investigate the work currently being conducted at the National Solar Energy Centre.

d Some people are concerned that harvesting food crops for biofuel production will result in food shortages. Research and report on whether these are valid concerns and recommend strategies to avoid this happening.

e Research the developments being made in 'clean coal' technology. List arguments for using coal-fired power plants in the future, with clean coal technologies. Also list arguments that could be made against the use of such power plants with or without the new technology.

f Some unusual devices are being tested to generate electricity from waves, with names such as 'the Oyster' and 'the Anaconda'. Summarise the development of one type of device designed to harness wave power and construct a model to explain how it works.

3 Research and report on how the solar energy complex shown in Figure 3.2.15 is used to generate electricity.

Figure 3.2.15 This solar energy complex located in the Mojave Desert in California, USA, is an example of a parabolic trough power plant.

3.2 Practical activities

1 Energy from food

The stored chemical energy in food can be used to produce biofuels. Food is also used as your chemical energy.

Purpose

To burn a sample of food and calculate its energy content.

Materials

- food samples such as: Cheezels, crusty bread, Marie biscuit
- cork
- aluminium foil
- paper clip
- retort stand and clamp
- thermometer
- test-tube
- electronic balance
- small measuring cylinder

SAFETY

Do not use peanuts or any nut product.

Watch the burning food sample at all times.

Ensure that the room is well ventilated or complete this experiment inside a fume cupboard.

Procedure

1. Using the measuring cylinder, carefully measure 10 mL of water. Pour it into the test-tube.
2. Cover the cork with aluminium foil. Shape the paper clip like a hook and poke it into the cork.
3. Cut a small piece of your first food sample. Record its mass in your table.
4. Set up the equipment as shown in Figure 3.2.16 so that the food sample will sit about 2 cm below the test-tube.
5. Measure and record the initial temperature of the water.
6. Use the Bunsen burner to set the food sample alight, and then carefully place the burning sample under the test-tube.
7. When the sample stops burning, measure the final temperature of the water and record this result.
8. Repeat the activity using two other food samples.

Results

1. Copy the results table below into your workbook.
2. **Calculate** the change in water temperature by subtracting the initial temperature from the final temperature.
3. For each sample, divide the change in water temperature by the mass of the sample.

Discussion

Compare the different samples and list them in order from the one that contains the most energy per gram to the one that has the least energy per gram.

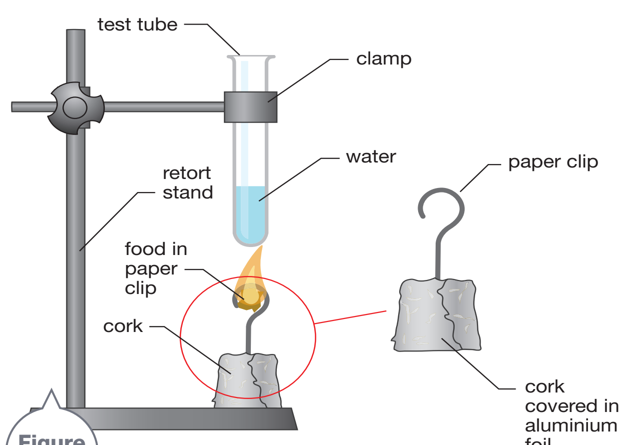


Figure 3.2.16

Food sample	Mass of sample (g)	Initial temperature of water (°C)	Final temperature of water (°C)	Change in water temperature (°C)	Change in water temperature ÷ mass of sample (°C/g)
1					
2					
3					

2 Harnessing the wind

Purpose
To investigate the effect that wind direction has on wind power.

Materials
- fan or a hairdryer
- pinwheel made from a sheet of cardboard (Please go to Pearson Places for a template.)
- nail
- bamboo skewer
- protractor (optional)
- masking tape
- cardboard cylinder
- length of string
- paper clip

Procedure
1. Produce a cardboard pinwheel using the instructions from Pearson Places and tape it securely to a bamboo skewer.
2. Support the pinwheel by inserting it through two holes in a cardboard cylinder as shown in Figure 3.2.17. The pinwheel and skewer should be able to spin freely.
3. Tape a length of string to the skewer where it extends from the cylinder.
4. Tie a paper clip or small sinker to the end of the string.
5. Investigate how the rate of spinning of the pinwheel (as indicated by the height the paper clip rises) is affected by the angle that the wind source (fan or hairdryer) makes with the front of the pinwheel. You could try different angles including 'straight on'.

Results
Present your data in a results table.

Discussion
1. **Describe** any patterns found in your results.
2. **Propose** any improvements that could be made to the design of your prac.

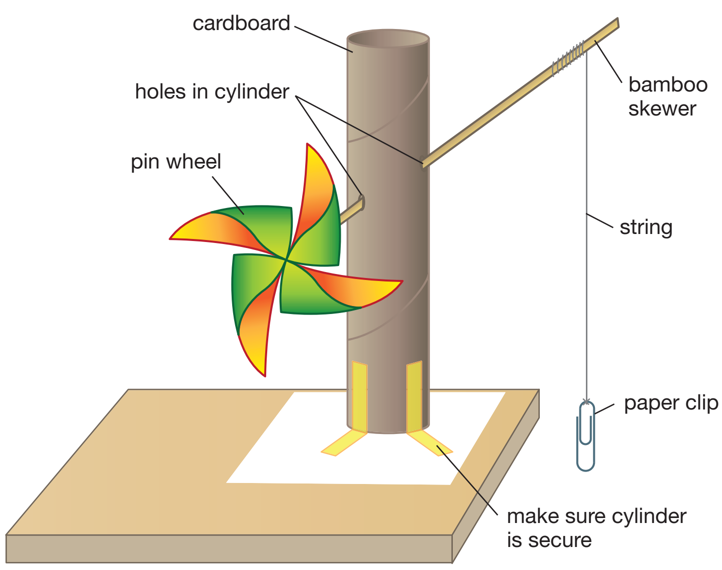


Figure 3.2.17 If the cylinder is unstable, tape it to a thick cardboard base so it is sturdy when standing upright.