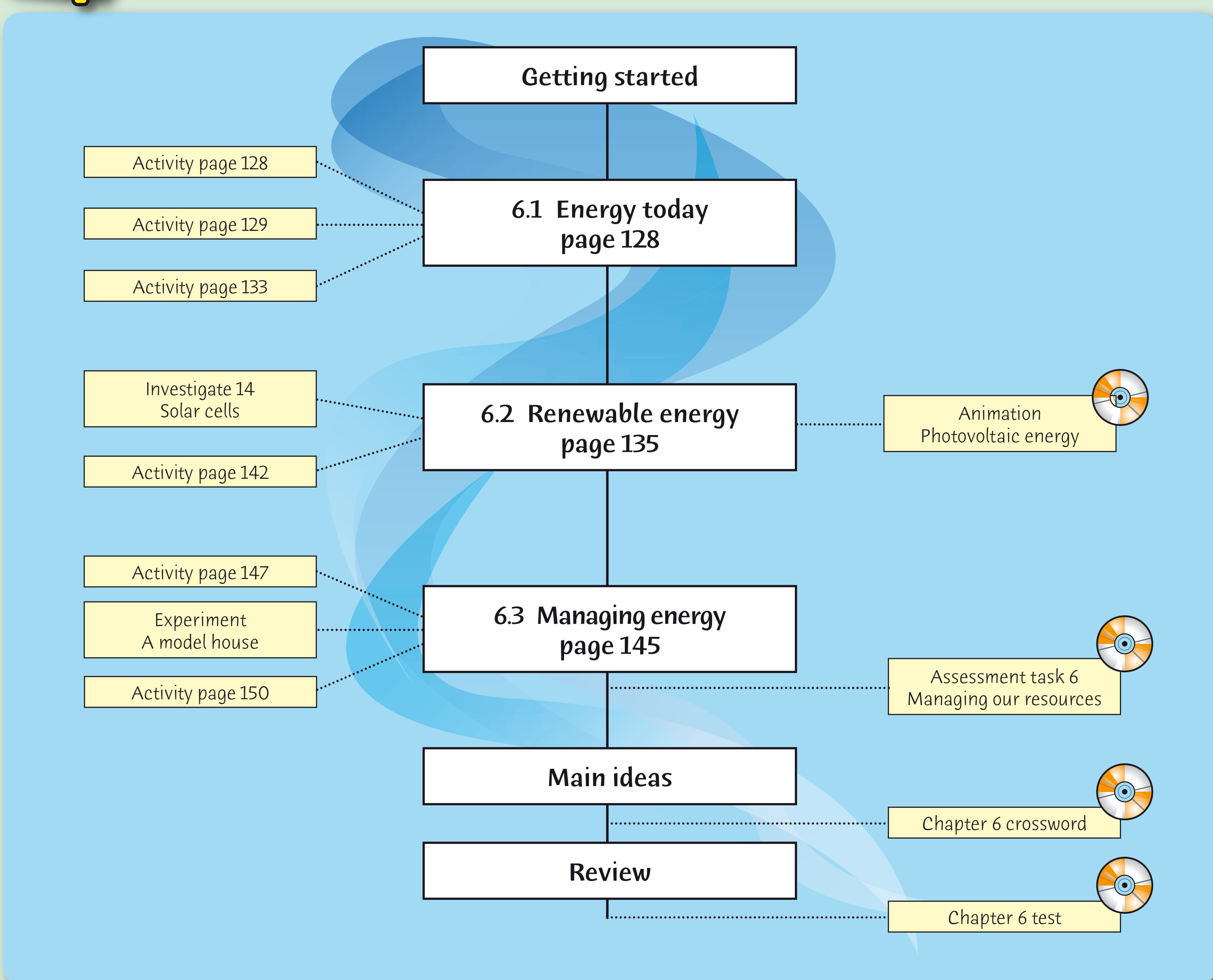
# 6 Our energy future

## Planning page



# Essential Learnings for Chapter 6

| *Essential Learnings* | *References* | | |
|---|---|---|---|
| | ***Student book (page number)*** | ***Workbook (page number)*** | ***Teacher Edition CD (Assessment task)*** |
| **Knowledge and understanding**<br>*Energy and change*<br>Energy is conserved when it is transferred or transformed | pp. 128–152 | | |
| *Science as a human endeavour*<br>Immediate and long-term consequences of human activity can be predicted by considering past and present events | Activity p. 133<br>Managing energy pp. 145–152 | | Assessment task 6<br>Managing our resources |
| Responsible, ethical and informed decisions about social priorities often require the application of scientific understanding | Activities pp. 129, 133, 142, 150<br>Extra for experts p. 139 | | Assessment task 6<br>Managing our resources |
| **Ways of working**<br>Draw conclusions that summarise and explain patterns, and that are consistent with the data and respond to the question | Activities pp. 128–129<br>Investigate 14 p. 137<br>Extra for experts p. 139 | pp. 41–42<br>p. 48 | |
| Communicate scientific ideas, explanations, conclusions, decisions and data, using scientific argument and terminology, in appropriate formats | Energy supply proposal p. 142 | pp. 43–47 | Assessment task 6<br>Managing our resources |
| Reflect on different perspectives and evaluate the influence of people's values and culture on the applications of science | Nuclear debate p. 133<br>Light of the world p. 151 | pp. 45–47 | |

*QSA Science Essential Learnings by the end of Year 9*

## Vocabulary

alternatives
appliances
biomass
consumption
efficiency
geothermal
hybrid
insulation
megawatts
methane
nuclear fission
photovoltaic
plutonium
radioactive
renewable
resources
sewage
turbine
uranium

## Focus for learning

Answer and discuss true/false questions on energy use in Australia (page 127).

## Equipment and chemicals (per group)

**Investigate 14 page 137** solar cell or panel of solar cells, small electric motor plus propeller, variable resistor or a range of resistors, milliammeter or multimeter, voltmeter or multimeter, connecting wires
**Try this:** light meter and sheets of translucent material

**Experiment page 148*** shoebox or similar box with lid, scissors, clear plastic (for windows), 2 thermometers or temperature probes and datalogger, insulation materials (eg corrugated cardboard, styrofoam, aluminium foil, woollen cloth), electric heater or high-wattage light bulb (optional)
**Try this:** materials for curtains, eaves and roofing

* Students to list the equipment they will need, which may be different from what is listed here.

# 6 Our energy future

## Getting Started

Working in small groups, decide whether each of the following is true or false. Afterwards you may be able to hold a class forum to discuss any questions where groups did not agree on the answers.

1 Coal, oil and natural gas are renewable resources.
2 Australia's coal reserves are predicted to last hundreds of years.
3 The Middle East has about two-thirds of the world's oil reserves.
4 Developing countries have about 50% of the world's population, but consume only about 10% of the world's energy.
5 Nuclear power stations do not produce greenhouse gases.
6 The reason there are no nuclear power stations in Australia is because we have no reserves of uranium.
7 Solar cells are almost 100% efficient.
8 Solar cells are 100 times cheaper than they were 25 years ago.
9 There are many wind generators connected to state electricity grids.
10 It is possible to generate electricity from the methane produced at rubbish dumps.
11 A small car uses less energy per person per kilometre than walking.
12 Electric cars are not as efficient as normal cars.
13 Fluorescent tubes use more energy than ordinary light bulbs.
14 Building a house with the living areas facing north can reduce heating costs.
15 It is possible for cars to run on hydrogen gas.


### Starting point

1 Students like to see how much they have progressed with their learning just as much as teachers like to see their students progress. Before the students work in small groups to answer the questions on this page, they could attempt to do them individually and hand them in for correction. At the end of the chapter the students can then be asked to answer the questions again. Hand back both sets of corrected answers to the students so that they can evaluate their progress. Most students will feel encouraged when they discover how much they have learned.
2 You could have a true/false style of questioning as a theme throughout this topic and regularly ask questions this way. Consider getting the students to make up their own sets of questions at the end of each section, then use the questions as a revision tool through the chapter.
3 Ask the class to do an 'Our energy future hunt' by scouring the daily news, magazines or electronic media for reports relating to this chapter. Get the students to pin their reports onto a noticeboard in the science room. If the item is in electronic form, they should clearly list the report's name, type of electronic media (TV article, electronic transcript, podcast and so on) and where the article can be located. Articles could be chosen at random, then read, watched or listened to by the class, and used as discussion starters. Has the reporter sensationalised the issue? What is the students' viewpoint? What did they know about the issue presented beforehand? A task like this helps the students to become more science-literate and to keep in touch with current science issues.
4 Students could develop a 'graffiti wall' around the theme of 'Our future energy'. Graffiti walls provide spaces for brainstorming or communicating words, concepts, ideas or questions about a topic. Make the task progressive so that it can be added to each lesson. A portable board is ideal to use as the 'wall'. It can be brought into each lesson so the students can add to or adapt it without interference from other classes. If you have an interactive whiteboard, make sure you save the document appropriately so it can be easily retrieved. Encourage the students to search for new and interesting facts or concepts, and to think of questions and possible answers.
5 Get the students to set goals for this topic about *what* they want to learn and *how* they could learn it. Not all goals should have the same learning method, so encourage creative thinking. About 10 goals are sufficient – five for *what* they want to learn and five for *how* they could learn it. Ask the students to scan through the chapter before writing their goals.
6 This topic is very dynamic. Information is continually being updated and viewpoints often change, mostly because of new technologies and research. When presenting information, make sure it is current and has been obtained from reliable sources. Remember to hold back your own opinions about an issue and to present balanced, scientifically factual information so that students can develop their own viewpoints.

## Hints and tips

This chapter has a large amount of text with fewer practical activities, so make sure you monitor students who experience language difficulties. Students with a language or learning difficulty could be encouraged to draw concept and flow diagrams to display information rather than write lengthy notes.

## Activity notes

- Sometimes data represented as percentages is more clearly interpreted when it is displayed as a pie chart. It would be a good challenge for the students to construct a pie chart using the data in the activity. It also helps link mathematics with science.
- Consider organising with the food technology department for the class to make their own bread. If this is not possible but you have access to a bread-making machine, use this instead. Making bread is not a quick process so time management is important.

## Homework

Can the students find data on the percentages of energy used to make or supply another type of food? It is often said that growing your own fruit and vegetables uses less energy than if you buy it. Can the students find evidence to support this? Students could present their information as pie charts, or as diagrams similar to the one shown in the Activity.

# 6.1 Energy today

## How much energy do we use?

Imagine how much electrical energy you would use if you ran three 1000 watt bar heaters continuously throughout the year. The energy used would be about 94 thousand million joules ($94 \times 10^9$ J). This might seem an enormous amount, but it is the average energy each person in Australia uses each year. It is almost four times the world average, and 12 times more than our neighbours in Indonesia use.

## How do we use energy?

In Australia we use 32% of our energy in industry, 41% in transport, 20% in homes and shops, and 7% in mines and farms. Much of this is in the form of electricity, but we also use large amounts of petrol and diesel for transport and industry, and gas for heating in our homes.

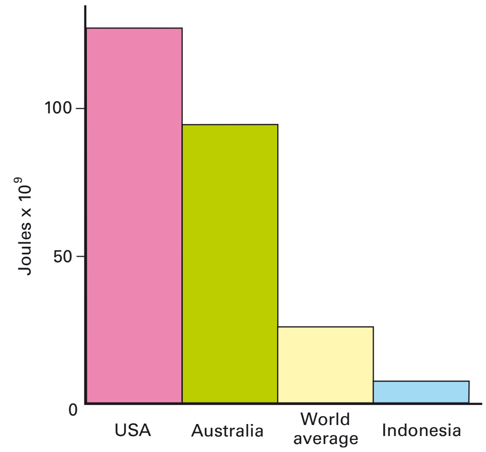



**Fig 2** Energy used per person per year in selected countries, based on data from *BP Statistical Review of World Energy*, June 2006

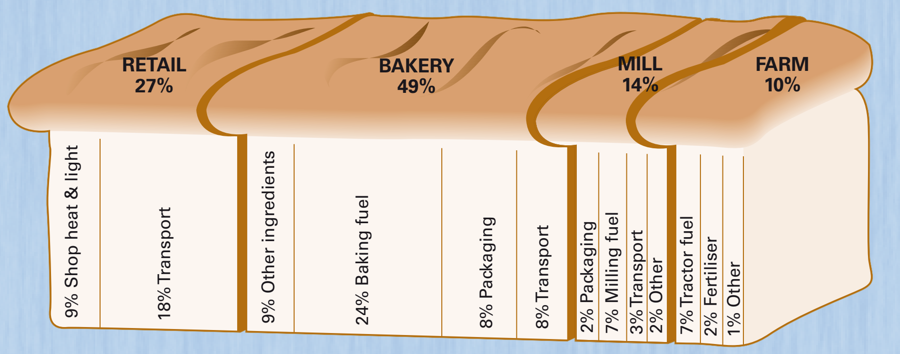
## Activity

The diagram below shows how much energy is used to make a loaf of bread.

What percentage of the energy needed to produce a loaf of bread is used to produce the wheat?

What percentage of the energy needed to produce the loaf is used in transport?

Do you think the amount of energy used to produce the loaf of bread could be reduced? How?




## Learning experience

If the students haven't already done so, ask them to do an online ecological footprint. Construct a class chart to see how many 'Earths' they need to sustain their lifestyle. For further information, go to *ScienceWorld 3* Webwatch and follow the link to 'Ecological footprint quiz'. A similar activity can be completed for their water footprint.

## Activity

| Energy reserves | 'Lifetimes' of world reserves from 2005 (in years) | Known Australian reserves in 2005 ($\times 10^{18}$ joules) | Annual Australian production ($\times 10^{18}$ joules) |
|---|---|---|---|
| oil | 41 | 8 | 0.4 |
| natural gas | 65 | 96 | 0.5 |
| coal | 155 | 632 | 3.3 |
| uranium | 70 | 366 | 5 (all exported) |

Source: *BP Statistical Review of World Energy*, June 2006, and data from Australian Uranium Association

Use the data in the table above to answer the questions below.

1 Which is Australia's largest energy reserve?

2 Use the equation below to calculate how long Australia's oil, gas, coal and uranium reserves will last at their present rate of use.

$$\text{lifetime} = \frac{\text{proven reserves}}{\text{annual production}}$$

| Australia's production and consumption of oil (in thousands of barrels per day) | | |
|---|---|---|
| **Year** | **Production** | **Consumption** |
| 1981 | 449 | 624 |
| 1984 | 568 | 611 |
| 1987 | 628 | 625 |
| 1990 | 651 | 694 |
| 1993 | 572 | 720 |
| 1996 | 619 | 794 |
| 1999 | 625 | 843 |
| 2002 | 731 | 846 |
| 2005 | 554 | 884 |

Source: *BP Statistical Review of World Energy*, June 2006

3 Compare the lifetimes for the Australian reserves with the lifetimes of the world reserves. What do you notice?

4 Use the data in the table bottom left to plot a graph showing how Australia's production and consumption of oil have changed between 1981 and 2005.

a Summarise in one or two sentences what the graph tells you.

b Is Australia a net importer or exporter of oil?

c Has our consumption of oil ever fallen? When?

d Was Australia ever self-sufficient (relying on its own oil without importing any)? When?

e Suggest reasons for the rises and falls in production.

f In which year did we import most oil? How much?

g If Australia's population was 20.3 million in 2005, how many litres of oil did each person use each day in that year, on average? (1 barrel = 159 L)

5 Oil makes up less than 1% of our energy reserves but 37% of our energy consumption. What does this mean for our future?

6 Why are we not using our reserves of uranium?

### Activity notes

- Quiz the students to check that they know how to represent the data in a graph. Ask questions like:
  - — What type of graphical display should be used?
  - — Which variable is the independent variable and why?
  - — What is an appropriate scale for your graph?
- It is a good idea to give a time limit for completion of this activity before reviewing it as a class. If you decide that students can finish it for homework, consider initialling each student's work at the point they have reached in class. By doing this, you can monitor how effectively they have used their time.
- You might be able to find some current tables of data for the students to use or to add to the data table in the activity. (The *BP Statistical Review of World Energy* can be accessed online.)

## Hints and tips

- Consider explaining to the class how fossil fuels are formed. This complex process could be presented as a flow diagram with simplified information. The flow chart could be expanded to include information about how the fuel is collected, refined and then used. This could also be a task for the students to research and complete.
- Acid rain is precipitation containing harmful amounts of nitric and sulfuric acids. It is formed mainly by nitrogen oxides and sulfur oxides which are released into the atmosphere when fossil fuels are burned (eg in cars and power stations), and by some industrial processes. Acid rain usually has a pH of less than 5.6.
- Photochemical smog (commonly known as smog) is a term used to describe air pollution that is the result of the interaction of sunlight with certain chemicals in the atmosphere. The smog often has a brown haze because of the presence of nitrogen dioxide.

## Research

Being exposed to smog can cause a number of health issues. Students could research this topic further and design a pamphlet about the chemistry of photochemical smog, possible health problems and how to reduce smog.

## Problems with fossil fuels

From Fig 4 you can see that in Australia we obtain 94% of our energy from fossil fuels—coal, oil and gas. These are **non-renewable energy** sources. Once used they are not replaced, or replaced only very slowly, by natural processes. On the other hand, hydro-electricity, solar, wind, tides and waves are **renewable energy** sources. 'Renewable' means that they are always available or can be replaced as they are used. Provided they are properly managed, they should not run out.

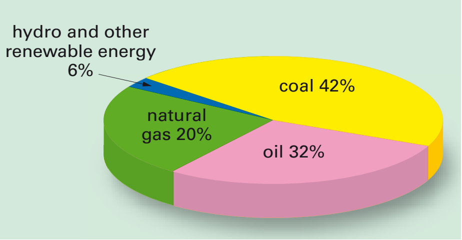



**Fig 4** Australia's energy consumption (2005)

Oil is widely used in industry and transport, but Australia has limited reserves of it. The pie chart below shows that some countries have more oil reserves than others. In 2005 Australia produced less than 70% of its own oil, and this percentage will decrease as our reserves are used up. Much of our oil will have to be imported from the Middle East, an area of the world that has been politically unstable.

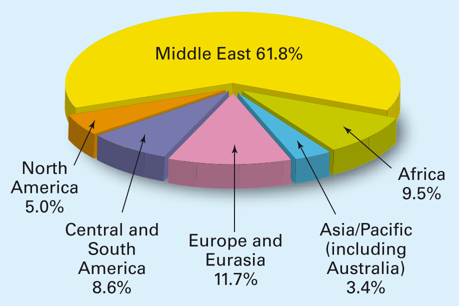



**Fig 5** World oil reserves in 2005

The other problem is that the burning of fossil fuels releases gases into our atmosphere. Increasing levels of carbon dioxide are likely to lead to global warming and climate change; and other gases can lead to pollution problems such as acid rain and photochemical smog.

We use almost all our oil as a fuel, but it may be wiser to use more of it to make other materials. For example, you might be surprised to learn that the oil needed to make 100 litres of petrol (about two tankfuls) could provide the raw materials and energy to make a large number of useful items: for example about 20 polyester shirts, 6 garbage bags, 20 acrylic jumpers, a car tyre, 20 bicycle tubes and 500 pairs of pantihose!

## The nuclear alternative

In contrast to fossil fuel power stations, nuclear power stations do not usually cause air pollution. The use of nuclear fuel not only conserves valuable fossil fuels, but also reduces greenhouse gas emissions and reduces the problem of acid rain. However, there are two major problems with the use of nuclear power: the disposal of highly radioactive wastes, and the risk of serious accidents occurring in nuclear reactors.

A nuclear power station uses the process of **nuclear fission**, and typically produces 25 tonnes of spent fuel each year (Stage 5 of the nuclear fuel cycle on the next page). Most of this spent fuel is uranium and plutonium which can be recycled (Stage 7), but there is almost 1 tonne of unused, highly radioactive material produced each year. These wastes can be solids, liquids or gases.

The first step in handling radioactive wastes is simply to let them sit for several months in shielded containers. The **half-life** of a radioactive substance is the time it takes for its radioactivity to halve. Substances with short half-lives decay enough to become safe during that time. However, substances with longer half-lives must be stored for hundreds, perhaps thousands of years and not allowed to escape into the environment.

For many years low-level wastes were cast into concrete, put into drums and then dumped at sea. This method of disposal has now been banned, because some drums started to leak. High-level

## Learning experience

What do the students know about non-renewable energy sources? What do they know about Australia's energy sources and usage? How does Australia's production and usage compare to that of other countries? Why is there a global push for using renewable energy? Are non-renewable resources used only for fuel? What else is oil used for? Before teaching the material covered in this section, give the students a true/false quiz to find out what they already know. The questions listed here might be a starting point for the quiz.

## Learning experience

Why are we being encouraged to reduce our usage of fossil fuels? Is it mainly because we are running out of them, or because they cause harmful pollution, or both? Get the students to design colourful posters, fact sheets or pamphlets explaining why we should reduce our consumption of fossil fuels. The target audience should be Australian households or Australian industry.

## Learning experience

If fossil fuels are decomposed plant and animal matter that lived millions of years ago, then it is very likely a dinosaur helped you get to school (petrol)! What do the students think of this? Can they come up with any of their own quirky but relevant thoughts, facts or questions? Allow them time to scan through the chapter or surf the internet. Information could be added to the graffiti wall (see Starting point, page 127), or written on cards to be collected and read aloud.

wastes are at present stored in large concrete ponds. The water stops radiation escaping and removes the heat produced by the radioactivity (Stage 6 below).

Scientists are investigating various methods for long-term storage of nuclear wastes. One idea is to solidify the wastes in glass and seal them in stainless steel canisters. These canisters would be stored in deep underground caverns such as old salt mines (Stages 8–9). An Australian scientist, Professor Ted Ringwood, invented an alternative rock-like material called *Synroc* for storing wastes, but this method is still being trialled.

The area where radioactive waste is buried must be free from earthquakes. Also, there are a number of questions about long-term storage which we simply cannot answer. For example, can we be absolutely sure of what will happen to the wastes over the next thousand years?

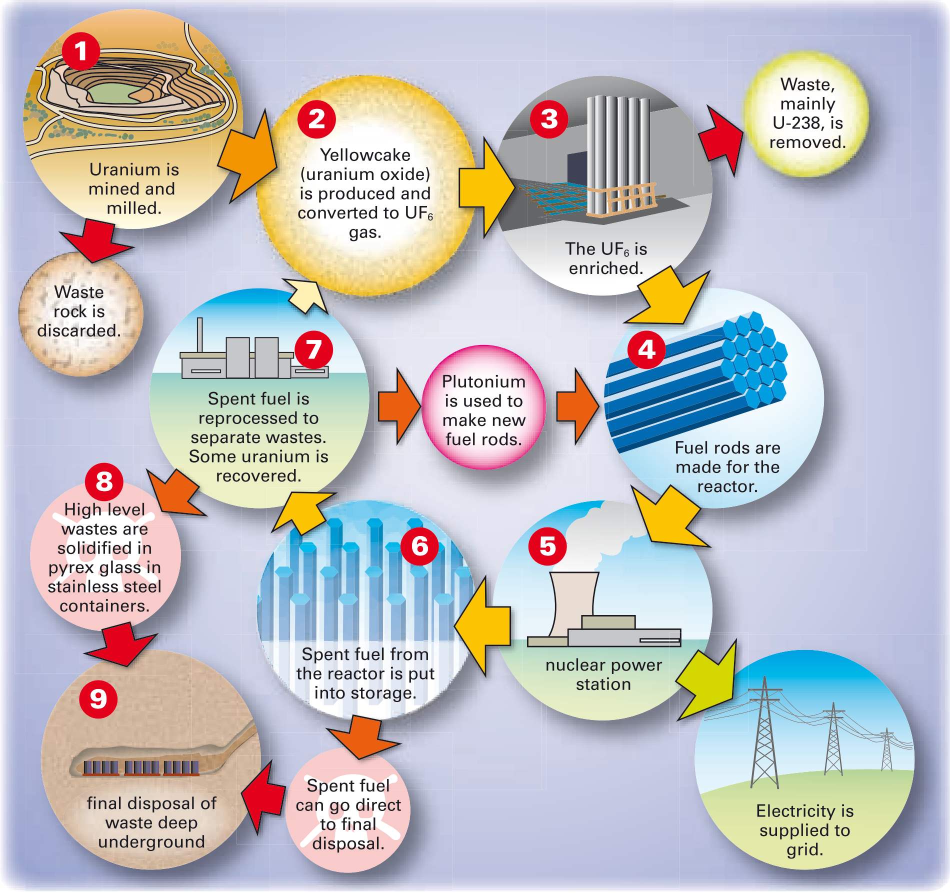



**Fig 6** The nuclear fuel cycle

## Learning experience

Have the students construct a '5W chart' around the theme of the nuclear alternative (see Learning experience, page 49). The central term should be 'The nuclear alternative' and there should be five branches or balloons extending from it for the Ws. Students then develop a series of questions using the five Ws and write them into the balloons.

## Learning experience

Using Fig 6, 'The nuclear fuel cycle', get the students to construct a flow or schematic diagram of this information. They could further expand it by researching and recording information about each process. Colourful posters, mobiles or electronic presentations would be good formats for their final product.

## Hints and tips

- Nuclear fission and fusion should not be confused. Give clear explanations of both. Revise the atom, especially the subatomic particles of the nucleus. A discussion about nuclear forces might be good here.
- It is important for students to know the meanings of the terms *nuclear enrichment*, *fuel rods* and *spent fuel*, and to understand what a nuclear power station does.

— Natural uranium mainly consists of a mixture of two isotopes of uranium. Less than 1% of natural uranium is capable of undergoing fission (splitting the atom). The fissile isotope of uranium is uranium 235 (U-235) and the other isotope is uranium 238 (U-238). Nuclear reactors require a much higher than natural concentration of U-235, so the uranium must undergo a process called *enrichment*.

— *Fuel rods* are long, slender tubes that hold fissionable material (fuel). The rods are assembled into bundles called fuel elements and loaded individually into the reactor core. New generations of nuclear power stations have been proposed which will use pebble bed reactors, thus eliminating the need for fuel rods. These reactors will be helium-cooled and will be able to be assembled in a safer and cheaper way.

— *Spent fuel* is nuclear fuel that has been irradiated in a nuclear reactor to the point where it is no longer useful in sustaining a nuclear reaction. It is a waste material from nuclear reactors that is highly radioactive and that releases a considerable amount of heat. Some of the elements will remain radioactive for a few years, while others will be radioactive for thousands of years.

— A *nuclear power station* converts the energy released from nuclear fission into electricity. Inside the nuclear reactor, the nuclei of U-235 atoms split (fission) and, in the process, release energy. This energy is used to heat water and turn it into steam. The steam is used to drive turbines connected to a generator, which produces electricity.

## Hints and tips

Do students know that they probably have some very radioactive material in their homes? Smoke detectors contain small amounts of americium-241. The alpha particles emitted by the americium ionise the air around the smoke detector, creating a small current that keeps the alarm from sounding. When smoke enters the detector, the ions are attracted to the larger smoke particles and this makes them move at a slower speed. This, in turn, causes the current to be reduced and it is unable to stop the alarm sounding.

## Issues

- Should the Lucas Heights reactor continue to operate? Students could explore how exposure to radiation can cause cancer and cure it, and some benefits and hazards of using radioisotopes. What are the issues surrounding this question?
- Divide the class into small groups, some to investigate positive aspects of using radioisotopes and some to investigate negative aspects. Students should start their investigation by brainstorming a list of questions to research, then ordering the questions and assigning them to team members to research. A team leader should be chosen who will present the group's findings to the class. An oral presentation with visual aids is the most suitable way to present information. When all groups have presented their part of the issue to the class, ask students to formulate a viewpoint about radioactive isotopes. Collect each written response for evaluation.

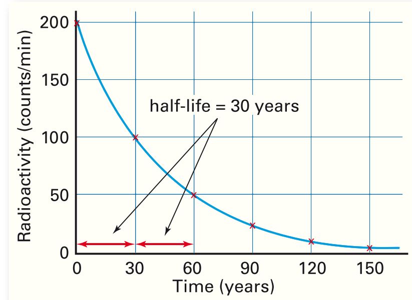
## Learning experience

Demonstrate how a Geiger counter works. If you have access to a portable instrument it is fun to take the students around the school and measure the radioactivity of different materials. (Radioactive laboratory samples, smoke detectors, human breath, pottery kilns and so on can be measured.)



## extra for experts

The half-life of a radioactive substance is the time it takes for its radioactivity to halve, or the time taken for half the atoms in a sample to decay. Suppose a substance has a half-life of 30 years. If the radioactivity is 200 counts per minute to start with, then in 30 years time it will be only 100 counts per minute. After 60 years it will be 50, and after 90 years it will be 25 counts/min. This information can be displayed on a graph.




While nuclear reactors normally release only small amounts of radioactivity, there have been a number of serious accidents: for example at Three Mile Island in the USA in 1979 and at Chernobyl in Ukraine in 1986.

The world's reserves of uranium are estimated at $1800 \times 10^{18}$ joules, enough for about 70 years at current consumption rates. Australia has about 30% of these known reserves, but all of the uranium mined in Australia is exported. At present there are 440 nuclear reactors in over 31 countries around the world, generating 16% of the world's electricity, but producing about 400 tonnes of highly radioactive waste each year. There are no plans to build nuclear power stations in Australia, although some people are starting to think about it. There is a small experimental reactor at Lucas Heights in Sydney. However it is not used to produce electricity. It is used only for research and the production of radioactive substances such as technetium-99 for use in medicine.

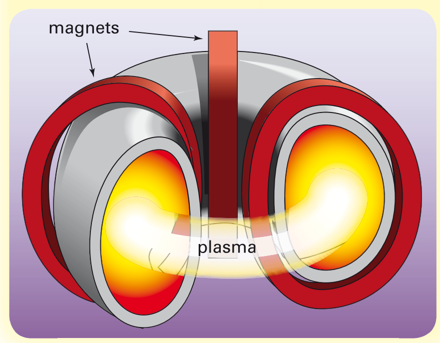
## Science in action

### Nuclear fusion

Current nuclear reactors use nuclear fission where you split large atoms of uranium to produce large amounts of energy. In **nuclear fusion** you produce energy when two small atoms join together to form a larger atom. For example, hydrogen atoms fuse to form helium atoms and neutrons. It's the same type of nuclear reaction that powers the Sun. For an animation of nuclear fusion, go to www.scienceworld.net.au and follow the links to **How nuclear fusion reactors work**.

The good thing about nuclear fusion is that it produces less radioactive waste than nuclear fission. Also, the fuel needed is almost unlimited. Deuterium, a form of hydrogen, is found in seawater. There are several experimental fusion reactors around the world, but no working reactors producing electricity.

To produce nuclear fusion you need a temperature of 100 million degrees Celsius—about six times hotter than the core of the Sun! At that temperature the hydrogen is a plasma, not a gas. You also need to squeeze the hydrogen atoms together using intense magnetic fields. Microwaves, electricity and particle beams from accelerators heat a stream of hydrogen gas, turning it into a plasma. This plasma is contained inside a doughnut-shaped magnetic field. The fast-moving neutrons that are released heat up a liquid which is then used to produce steam.



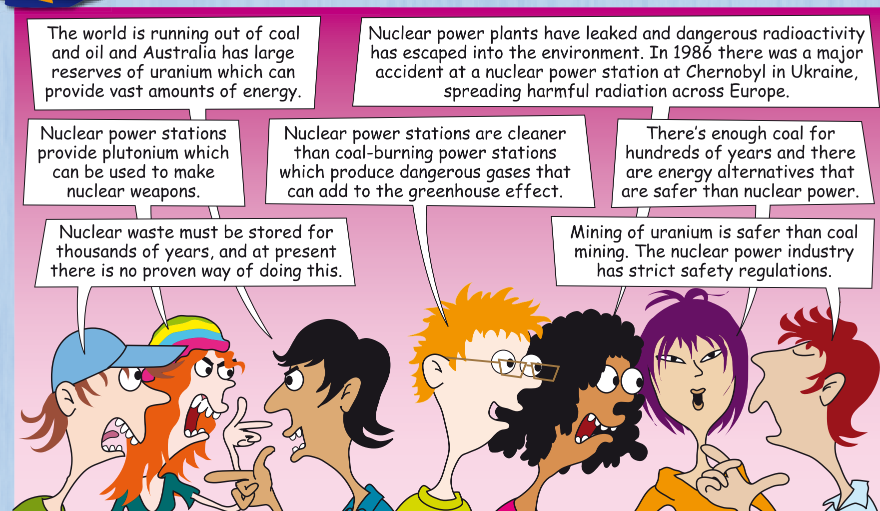

## Learning experience

Get the students to do a half-life simulation and draw a graph of their results. Groups of students will need a small packet of M&Ms and graph paper. Students count the initial number of M&Ms in the packet. This is their radioactive sample. They put the M&Ms back in the packet and then tip them out onto a sheet of paper. Students eat the lollies with the M&M label facing up, and count the remainder of the sample. They repeat this process until no more M&Ms are left. Results should be recorded in a table and graphed. A very good half-life curve should be obtained. Remember to be aware of students with food allergies or intolerances.

## Learning experience

Investigate the half-lives of radioactive substances in greater detail. Ask the students to use books, encyclopaedias or the internet to find out the half-lives of some common radioisotopes such as radon-222, technetium-99, iodine-131, americium-241, carbon-14, plutonium-239 and uranium-238. Construct a class table and work through an exercise showing how much of a given sample of a radioactive isotope is left after, say, five half-lives. (Some smoke detectors contain about 0.5 g of americium.) Mathematically keen or gifted and talented students could find out and use the formula for half-life.

## Activity




The debate about nuclear power has been going on for years. Since nuclear power stations were first built many people have vigorously opposed them. Others are just as strongly in favour of them. The main arguments for and against uranium mining and the use of nuclear power are summarised in the cartoon.

**Postbox activity**

On your own, answer each of the six questions opposite. Write each answer on a separate piece of paper and put them in the numbered boxes.

Form groups of about four, go through all the answers in one of the boxes and decide what is the correct answer. Report your answer to the class.

For extra information go to www.scienceworld.net.au and follow the links to these two websites. One is pro-nuclear and one anti-nuclear.

**Uranium Information Centre**

**ANAWA Anti-Nuclear Alliance**

1. What are the details of the nuclear accident at Chernobyl in 1986?
2. How many nuclear power stations are there in other countries? What percentage of the total electricity produced in these countries is nuclear?
3. Which produces cheaper electricity—a coal-burning power station or a nuclear power station?
4. Where in Australia is uranium mined? To which countries is it exported?
5. How does exposure to radioactivity affect people?
6. What is presently done with radioactive wastes? What future plans are there?

Here are some other things you could do:

- Have a debate for and against nuclear power.
- Role play an inquiry which has been set up to decide whether or not a nuclear power station should be built near your home.
- Write a letter to the editor of a newspaper in favour of or against nuclear power.

## Activity notes

- This is a good activity but will need to be well planned and is best conducted over several lessons.
- If students are going to debate the issue, each group could appoint the following:
  - **Team leader and timekeeper** keeps the group on task, ensures all members of the group have the opportunity to contribute, is responsible for monitoring the progress of the group, liaises or negotiates with the teacher, contributes appropriately to discussion, listens to others and monitors progress according to the group's timeline.
  - **Recorder** listens carefully to the discussion, records the main points, records decisions made by the group and any other points as directed by the team leader, has notes checked by others for reliability, and contributes appropriately to discussion.
  - **Researcher(s)** gather(s) information/resources for the group, liaises with the team leader, monitors the use of resources, gathers more resources when needed, contributes appropriately to discussion and listens to others.
  - **Reporter** may be called upon to report to the class, restates decisions and discussion points to the group members, contributes appropriately to discussion and listens to others.
- When debating the issue, remind students of the rules for cooperative debating.
- At the end of this activity, ask students some interpersonal or collaborative questions which focus on their interactions with other members of the group or class. Doing this helps students to think about their learning and how they can assist others with theirs. Consider questions such as:
  - What did you learn about your partner?
  - How well did your group work together and why?
  - What help did the group members give to each other and how did it affect your group?

### *Homework*

In December 2006 it was reported that a former Russian spy, Alexander Litvinenko, died from radiation poisoning. Ask students to find out more about his death and how the radioactive polonium was traced back to Litvinenko's alleged killer. What were Litvinenko's symptoms? How is it believed that he received the poison? Where did the radioactive source come from? Students can write their own media report to answer the questions about Litvinenko's death. These reports need to be factual, scientifically accurate and include a bibliography.

### *Learning experience*

Although Australia has no nuclear power reactor, it does have a nuclear research reactor at Lucas Heights in Sydney. The reactor is used to produce radioisotopes for medicine, research and industry, which are then used at hospitals, industrial sites and laboratories around Australia. Each year about 45 cubic metres of radioactive waste is produced from manufacturing and using these isotopes. The waste is stored at over 100 sites around Australia. Ask the class to investigate why the storage of this waste is not considered suitable as a long-term strategy.

## Check!

1 What is the difference between a non-renewable and a renewable energy source? Give an example of each.

2 a List reasons for looking for energy alternatives other than fossil fuels.
  b Why is finding a replacement for oil and gas more urgent than finding a replacement for coal?

3 Compare and contrast nuclear power stations and coal-burning power stations.

4 About 100 years ago the Russian chemist Dmitri Mendeleev said that burning petroleum 'would be akin to firing up a kitchen stove with banknotes'. Why do you think he believed petroleum was too valuable to burn?

5 Energy is used to produce the many foods we take for granted—for example, a loaf of bread (page 128). Think of a food and list the ways in which energy is used to provide the finished wrapped product ready for you to eat.

6 Suppose there is a leak in a nuclear reactor and highly reactive strontium-90 is released into the surrounding countryside which is used for dairy farming. Two months later breastfed babies are found to have small amounts of strontium-90 in their bodies. Explain how this could have happened.

7 Use the internet to find out what oil shale is, where it is found in Australia, and how it can be converted to oil.

## challenge

1 The table shows the total nuclear energy produced in the world from 1981 to 2005.
  a Display the data on a line graph. (You will be predicting up to the year 2020, so think carefully about the units for the axes.)
  b Do you think nuclear energy production was affected by the Chernobyl disaster in 1986? Explain.
  c Use your graph to predict the nuclear energy production in 2010 and 2020.
  d Which one of your predictions is likely to be more accurate? Explain.

| Year | Nuclear energy production (million tonnes of oil equivalent) |
|---|---|
| 1981 | 189 |
| 1984 | 282 |
| 1987 | 393 |
| 1990 | 453 |
| 1993 | 495 |
| 1996 | 545 |
| 1999 | 571 |
| 2002 | 611 |
| 2005 | 627 |

  e Compare your predictions with those of other people. How much variation is there? Mark the range of predictions for 2020 on your graph.
  f List factors which you think may increase the use of nuclear energy over the next 20 years. Also list factors which may decrease its use.

2 Use the nuclear fuel cycle on page 131 to answer these questions.
  a Which stages in the cycle produce wastes?
  b What happens at Stage 7?
  c Which is the longest stage?

3 You have 64 g of a radioactive substance with a half-life of 5 days. How much will be left after 5 days? After 10 days? How many days will it take for the mass to decrease to 1 g? Show this information on a graph.

4 Given that we are so short of oil, do you think that oil exploration should be allowed in environmentally sensitive areas such as the Great Barrier Reef? You could have a debate.

5 Use the internet to find answers to these questions:
  a What is the enhanced greenhouse effect?
  b What is the Kyoto Protocol?
  c What is carbon emissions trading?

## Check! solutions

1 As the names suggest, some energy sources can be renewed or replaced in a relatively short time, whereas others will never be replaced when used up. Fossil fuels such as oil and natural gas are examples of non-renewable fuels, and solar energy and 'biomass' are renewable.

2 a Alternative fuels are being investigated because the amount of fossil fuels available is limited and will eventually run out. Their combustion also causes pollution and changes in the composition of the atmosphere, which may lead to climatic changes.
  b The reason is that there are much greater known reserves of coal, which will last much longer than oil or gas.

3 Both types of power stations are similar because they require a source of fuel and produce waste products. The principle is also similar in that they both produce heat, which is used to boil water to make steam to turn a turbine and a generator. The differences are mainly in the type of fuel used and the nature of the products. A coal station produces carbon dioxide and other gases, which are released into the atmosphere, whereas a nuclear station produces solid, liquid or gaseous wastes that are radioactive and must be disposed of safely.

4 Even 100 years ago, scientists realised that petroleum contained a mixture of chemicals that were too useful to simply burn. Today, these chemicals are used to make a range of plastics, synthetic clothing, tyres and tubes for vehicles. Mendeleev also realised that petroleum was a limited resource and would eventually run out, which is what is happening now.

5 Your list will be similar to the one shown for bread on page 128. In ice-cream, for example, the raw materials (dairy products) require refrigeration and transport. They then need to be processed, packaged and frozen, which requires more energy. Finally, they are transported to the shop and stored in a freezer in a shop, which also requires energy.

6 The element strontium-90 would have been taken up from the soil by plants, which were then eaten by the cows. The radioactive element would have been absorbed into the cows and would then be present in their milk. This milk or products made from it (eg cream or cheese) would have then been consumed by the mothers and the radioactive substance would be present in their breast milk and, consequently, passed into the bodies of the babies.

7 Oil shale is any fine-grained sedimentary rock that contains organic material which can be extracted by heating and used as a fuel. In some cases it looks like coal. Another form found in the Blue Mountains in New South Wales is called kerosene shale. Oil shale has been used for more than 100 years in Scotland and elsewhere in the world, and a mine is being developed in central Queensland. This form of fossil fuel will become more attractive as deposits of petroleum are used up. Unfortunately, a lot of energy is required to mine it, and it is a fuel that emits carbon dioxide and other greenhouse gases.

## Challenge solutions

See page 331.

# 6.2 Renewable energy

At present we obtain about 94% of our energy from fossil fuels. However, some time in the near future these *non-renewable* resources will run out. We will then have to rely on *renewable* energy sources.

The largest energy source available to us is the Sun, and most of the renewable energy sources described in this section involve the Sun's energy—either directly, for example in solar water heaters, or indirectly, for example in plants grown by photosynthesis using the Sun's energy. Not all the renewable energy sources described are economically viable at present. However, as the prices of existing fossil fuels increase, the use of renewable resources will become more economical.

It is important that you have some knowledge of the range of energy alternatives described on the following pages.

## Solar energy

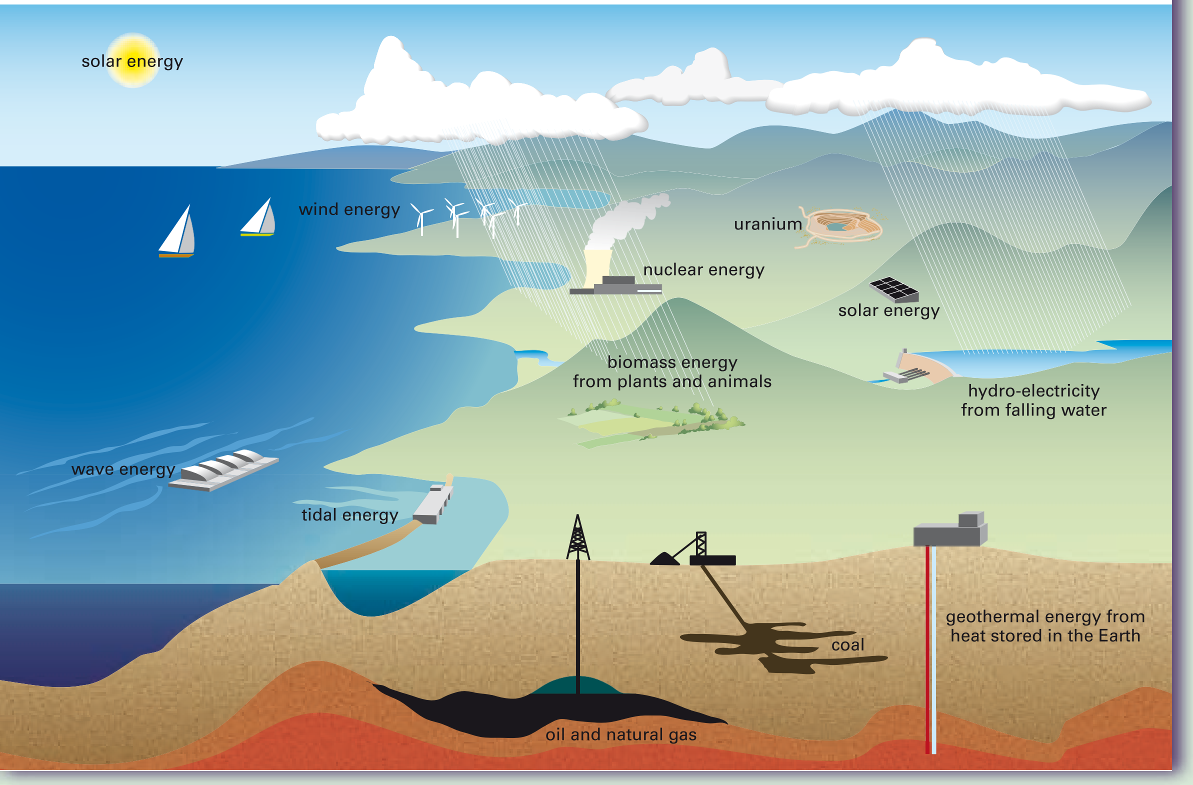
The solar energy striking the Earth every minute is enough to supply the world's energy needs for a year! Most of this solar energy is transformed to heat on the Earth's surface, where it produces winds and waves. A smaller amount of solar energy is absorbed by plants during photosynthesis.

Solar energy can be harnessed in two main ways: for the production of electricity and for heating, for example in solar water heaters.

### Solar cells

The Mars *Pathfinder* rover that landed on Mars in July 1997 was powered by *photovoltaic cells* or **solar cells**, which can convert light energy into electricity. The first solar cells were only 6% efficient, but efficiencies more than 30% are now possible.

**Fig 10** Which of these energy resources are renewable and which are non-renewable?




## Hints and tips

- Before starting any new material, have the students document and prepare the key points from the last few lessons. How much they can recall will determine how much time you need to spend on review before moving on to more advanced concepts. Another way to revise is by asking them to write a paragraph about what they have learned so far and share it with the person next to them. Choose a few students to read aloud their paragraphs to share with everyone. It is always good for the class to realise how much they have learned.
- Have a quick true/false quiz to find out what students know about renewable energy, in particular solar energy. You could give them a handout of the questions to complete in class, and then ask them to check their answers as the lesson progresses or for homework.

## Learning experience

At one time Australia was considered one of the world leaders in solar technology. Now Japan, Germany and other western European countries are. What do you think are possible reasons for this shift in solar technology leadership? Brainstorm as a class and add points to the graffiti wall developed earlier.

## Learning experience

Get the students to compile a series of 'Did you know …' facts about renewable energy. A database displaying the facts could be put on the school intranet and students could rate each one according to their interest. Make sure to remind students to cite their fact source. Alternatively, colourful cards could be made to display the information. Encourage unusual and interesting facts such as:

- A Queensland power plant is producing electricity by using waste macadamia nut shells.
- In Queensland, there is enough energy produced by burning sugarcane by-product to power a small town. (What use does sugarcane by-product currently have?)
- Toronto, next to Lake Ontario in Canada, uses the near-freezing water of the lake in summer for air conditioning. The water is pumped through pipes and is used to cool office buildings before being returned to the lake. (What environmental implications might arise from this?)
- Iceland's unique geological structure, with a large number of volcanoes, means it has an abundance of geothermal energy. This energy is most often used for heating and producing electricity. The energy is so inexpensive that some footpaths in the capital, Reykjavík, are heated in the winter.

### Hints and tips

Because this topic has a lot of text, make sure you are monitoring students who experience language difficulties. Where appropriate, suggest they take notes in point form, with clear page references, or suggest they do concept drawings to display information. Students with a preferred auditory learning style could make their own podcast or MP4 file of the text and revise the material this way.



The use of solar cells has become widespread in devices such as watches and calculators. They are also used to provide power to homes in remote areas, to pump water, and to operate roadside signs and street lighting systems.

There are three disadvantages of generating electricity using solar cells. Firstly, they are expensive. Secondly, they are less effective in cloudy weather and do not operate at night. Thirdly, large areas of land are needed for collection areas due to their relatively low efficiency. However, as the cost of solar cells decreases and their efficiency increases, they will almost certainly become more widely used. They are already 100 times cheaper than they were 25 years ago!

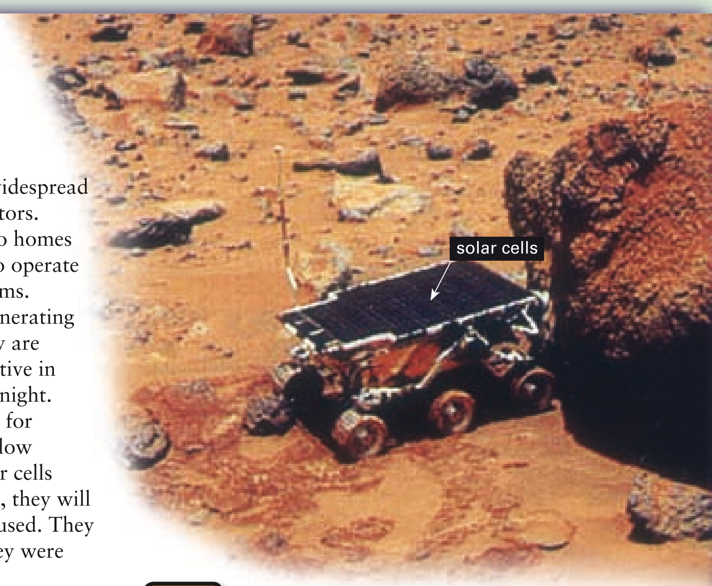



**Fig 11** The Mars *Pathfinder* rover

## Science in action

For an animation of how a solar cell works, go to www.scienceworld.net.au and follow the links to **Photovoltaic energy**. Working with technology

### Green power

Each year the Australia Prize is awarded in an area of science and technology promoting human welfare. In 1999 it was awarded to Martin Green and Stuart Wenham from the University of New South Wales for their pioneering work with solar cells. For almost 20 years they held the world record for the most efficient solar cells. These cells were used by the winning car in the 1999 World Solar Challenge.

Green and Wenham worked with an Australian company called Pacific Solar (now CSG Solar). They worked out a way of depositing thin layers of silicon onto glass sheets, instead of using expensive silicon wafers. This cut the cost of solar power by two-thirds. Ten modules of these solar cells mounted on your roof will generate 1 kilowatt, about a third of the electricity you need. In doing so they will reduce greenhouse gases by almost 2 tonnes every year.

The modules can be fitted together like Lego blocks. They convert DC electricity to AC suitable for running lights and appliances in homes and offices. Any surplus electricity is automatically fed back into the electricity grid through the meter box, giving the owner a credit on their bill.

**Fig 12** These solar panels generate electricity directly from sunlight.

### Homework

List some items that could be solar-powered and have the students choose one of them. They are to consider how the item might work if it were solar-powered, and its benefits and problems. How would they design the item so that it is effectively solar-powered? What alterations and/or design features would they make/incorporate? A simple diagram should be drawn to outline the item's features. Possible items to consider are: notebook computer, mobile phone, iPod or MP4 player, digital camera, hot water system, street lighting.

### Learning experience

There is a $420 million solar photovoltaic power station planned for north-west Victoria. Get the students to find out more about this proposal: when and where it is going to be built, when it will be in operation, how much of Victoria's electricity is going to be supplied by it, how the electricity will be supplied, and how cost-effective it will be in the short-term and long-term. Students could make an advertisement promoting this renewable energy alternative.

### Learning experience

If the students haven't previously designed and constructed a solar cooker to toast a marshmallow, now would be a good time. Further instructions can be found in *ScienceWorld 2 Teacher Edition*, page 58.

### Learning experience

Solar cells are becoming more efficient and cheaper to manufacture. In the year 2020 they might be so cheap that many portable everyday items will be powered by them. What might it be like to live in this time? How old will you be and what do you think you will be doing? Students could write a creative story, diary entry or cartoon strip detailing what life might be like.

# Investigate 14 SOLAR CELLS

## Aim

To investigate the efficiency of a solar cell or solar panel.

## Materials

- solar cell or panel of solar cells
- small electric motor plus propeller
- variable resistor or a range of resistors
- milliammeter or multimeter
- voltmeter or multimeter
- connecting wires

### Planning and Safety Check

Read through the investigation and design a data table.

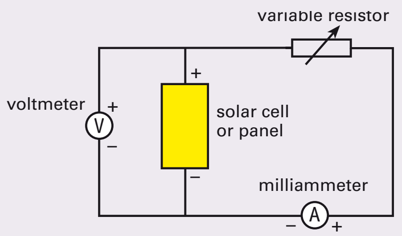
## Method

1 Connect the solar cell or panel to a small electric motor (preferably fitted with a propeller). Put the cell in bright sunlight and observe how fast the motor turns.

What is the effect of placing your hand over the cell?

Is the angle of the cell in relation to the Sun important? Which angle is best?

2 Set up the electrical circuit as shown in the diagram.




3 Place the solar cell or panel so that sunlight falls directly onto it.

4 Set the variable resistor to zero resistance and measure the current and voltage.

Record these values in your data table.

5 Increase the resistance in steps, recording the voltage and current each time. Stop when further increases in resistance have little effect on the current or voltage.

## Discussion

1 For each value of the resistance, calculate the power output of the cell or panel using the following formula:

**power (watts) = voltage (volts) × current (amps)**
**or $P = VI$**

Add the power values to the data table.

2 Draw a graph of power versus resistance.

What is the maximum power of your cell or panel? At what resistance does this occur?

3 How many solar cells like yours would be needed to power a 60 watt light bulb?

4 If the maximum power required by a household during the day is 3000 watts, calculate the number of solar cells like yours you would need, assuming sunny conditions.

5 What is the efficiency of the solar cell, assuming the average available power of sunlight is about 1000 watts per square metre?

You will need to measure the surface area of the solar cell to find the maximum power *per square metre*.

$$\text{efficiency} = \frac{\text{power of cell}}{\text{power of sunlight}} \times 100$$

### try this

- How does the angle at which the cell or panel is positioned affect its output?
- How does the light intensity affect the power output? (Use a light meter.)
- How does cloud cover affect the output? (To simulate cloud cover you could hold sheets of translucent material over the cell.)

### Lab notes

- You will probably need access to an outdoor area on a bright sunny day for this investigation to be successful.
- Check that the voltmeters/ammeters/multimeters are correctly set up and correctly used.
- Spend time going through the discussion questions as a class.

### Solar power stations

At Liddell Power Station near Muswellbrook in NSW a solar power system is being built beside the coal-burning power station. It consists of a giant array of flat mirrors which will eventually cover an area the size of four football fields. The mirrors track the Sun and concentrate its heat onto what is in effect a huge solar hot water system. The heated water is pumped into the power station where it is heated further to produce high-pressure steam to drive turbines and generate electricity. This solar power system will cut down on the amount of coal needed to produce our electricity.

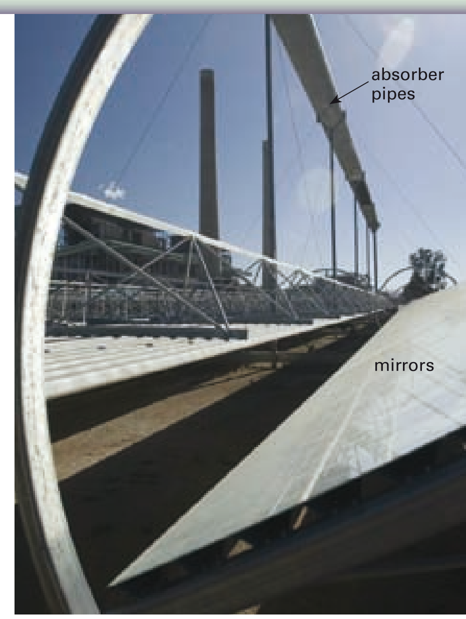



**Fig 14** The Solar System at Liddell Power Station

## Wind energy

Windmills have been used in Australia for many years to pump water. Only recently have wind generators been used to produce electricity.

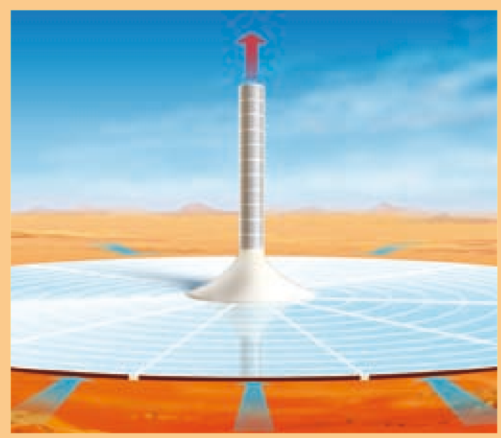
A small wind generator can produce 40–50 kilowatts, enough electricity for a single house. A huge generator whose blades sweep a circle 80 metres in diameter can produce 1.65 megawatts of electricity. A normal coal-burning power station generates about 2000 megawatts, so you need 1200 wind generators to produce the same amount of electricity as a single power station!

Australia's largest wind farm is at Wattle Point on the Yorke Peninsula in South Australia (see Fig 16 on the next page). It has 55 wind turbines and generates enough electricity to supply more than 55 000 homes. Each turbine is 68 metres tall and the blades are 41 metres long. The largest wind farm in Queensland is at Windy Hill on the Atherton Tablelands.

### Solar power tower

*A Melbourne-based renewable energy company called EnviroMission is planning to build a solar power tower near Wentworth in south-west NSW. The proposed tower would be a kilometre high—the world's tallest structure. Around the base of the tower there would be a circular 'greenhouse' canopy of transparent plastic, about 5 km in diameter. The air under the canopy would heat up and rise up the central tower at 35–50 km/h. This rising air would spin 32 turbines mounted 40 m above ground level, generating 200 megawatts of electricity—day and night. This would be enough electricity to supply 200 000 homes.*

*A recent report written by CSIRO scientists estimates that a 35 square kilometre area with plenty of sunlight and little cloud could produce all Australia's electricity using solar power systems like this and the one at Liddell.*



### Hints and tips

Colourful posters are a good way for students to summarise and simplify information. Get the class to make posters to display around the room using the information in this section. Pairs of students could choose a renewable energy type to focus on. Make sure each energy type is represented.

### Research

Students could find out how Australia's production and usage of renewable energy compares with other countries. They could also try to find global figures for each type of energy used (ie which country produces and uses the most of each energy type). Ask the students to construct lists detailing this information. Their list should contain no more than 10 countries when comparing energy statistics with Australia. From their list they should choose three countries and explain why they think the energy statistics are different. Which country produces/uses most renewable energy? Why? How does Australia compare? What can be learnt from this? What renewable energy does Australia use, where is it being produced, how is it being used and who uses it? Visual display booklets or interactive PowerPoint slides with hyperlinks might be a good way for the students to present their research. A useful website can be found in the *ScienceWorld 3* Webwatch for Chapter 6. Follow the links to 'List of renewable energy topics by country'.

### Learning experience

If students create their own posters (Hints and tips, above), conduct a quiz based on the information on the posters to see what students can remember. The quiz could be a true/false format:

- All members of the class stand up.
- Ask the students a question or a statement related to the topic.
- If the students think it is true, they put their hands on their heads; if they think it is false, they put their hands on their hips.
- Students who answer the question incorrectly sit down; those who answered correctly remain standing.
- Continue this process until you have a winner.

You might like to reward the winner with a small prize, like a capacitor-charging or hand-winding torch.

## extra for experts

### Wind generators

The power output of two different-sized wind generators was measured at different wind speeds, and the results recorded.

| Wind speed (m/s) | Power output (watts) | |
|---|---|---|
| | Rotor blade diameter 3 m | Rotor blade diameter 6 m |
| 2 | 15 | 60 |
| 4 | 120 | 475 |
| 7 | 400 | 1 600 |
| 9 | 950 | 3 600 |
| 11 | 1 840 | 7 360 |
| 13 | 3 180 | 12 760 |

1 Plot two line graphs on the same axes to show how power output varies with wind strength. Label the graphs carefully.
2 Write two generalisations about the power output of wind generators.
3 Use the data to work out what happens to the power output when the wind speed doubles.
4 A phone company wants to power outback telecommunication equipment that needs 1.5 kW to operate. Wind speeds in the area vary from 7 m/s to 11 m/s.
 a Which generator would be more suitable—the one with 3 m blades or the more expensive one with 6 m blades?
 b Would the generator you chose still be suitable in an area where the wind speed varies from 6 to 10 m/s? Explain.
5 The power that can be obtained from a wind generator operating at 50% efficiency can be calculated as follows:

power (watts) $= 0.3 \times A \times v^3$

where A = area in $m^2$ swept by the blades and v = wind speed in m/s.

 a Calculate the power produced by a wind generator with 10 m diameter blades operating in a 10 m/s wind.
 b Use the equation to work out what happens to the power when:
 - the wind speed doubles
 - the diameter of the blades is doubled.
 c Are the wind generators in the table operating at 50% efficiency? Explain.

Fig 16 Wattle Point wind farm in South Australia

### Hints and tips

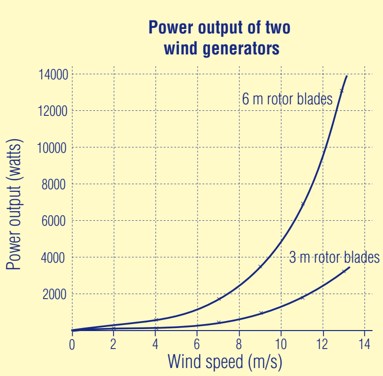
Go through this exercise with the class. Be sure to check that students experiencing difficulties with their mathematics are given adequate attention. While individual work should be encouraged, it might be helpful to appoint fast-working students to help those needing extra assistance.

### Homework

Students could write some 'what', 'how' and 'why' questions relating to types of renewable energy. They need to be specific when writing their questions. Questions can be collected in the following lesson and discussed as you work through the topic.

### Extra for experts solutions

1




2 As the wind speed increases, so does the power output. The larger the rotor blade diameter, the larger the power output.

3 When the wind speed doubles from 2 m/s to 4 m/s the power output of the 3 m rotor blade increases 8 times (from 15 watts to 120 watts).

4 a From the graph you can see that the small generator only produces 1.5 kW (1500 watts) when the wind speed is more than 10 m/s, so it is not suitable. The large generator produces more than 1.5 kW at all speeds from 7 m/s to 11 m/s.
 b Yes.

5 a $A = \pi r^2$
$= 3.1416 \times 5^2$
$= 78.5\ m^2$
power $= 0.3 \times A \times v^3$
$= 0.3 \times 78.5 \times 10^3$
$= 23\,550$ watts
 b If the wind speed doubles:
power $= 0.3 \times 78.5 \times 20^3$
$= 188\,400$ watts
So the power increases by a factor of 8.
If the diameter of the blades is doubled:
$A = \pi r^2$
$= 3.1416 \times 10^2$
$= 314.2\ m^2$
power $= 0.3 \times A \times v^3$
$= 0.3 \times 314.2 \times 10^3$
$= 94\,260$ watts
So the power increases by a factor of 4.
 c From the table, a 3 m generator in a 7 m/s wind produces 400 watts:
power $= 0.3 \times A \times v^3$
$= 0.3 \times (3.1416 \times 1.5^2) \times 7^3$
$= 727$ watts
A 6 m generator in a 7 m/s wind produces 1600 watts:
power $= 0.3 \times (3.1416 \times 3^2) \times 7^3$
$= 2909$ watts
So the generators in the table are not 50% efficient—only about half that (25%).

### Hints and tips

Take a few minutes to revise and reinforce past work in this chapter. The students could write down a paragraph or jot down a series of dot points about what they have learned so far, then share it with the person next to them. Ask them to write down an area they found challenging and why, if they would like it reviewed, and what they feel they have grasped or understood well. Collect their responses to evaluate.

## Biomass

**Biomass** is plant and animal material used as a source of renewable energy. It may be wood from forests, residues from agriculture and industry, or human and animal wastes.

In Australia we throw away over 10 million tonnes of household rubbish every year. Much of this is biomass and contains about the same energy as 3 million tonnes of coal. This rubbish can be used to produce electricity, as shown in Fig 17. When it is dumped and covered with soil, the breakdown of biodegradable materials produces *biogas*, which is mainly methane. PVC pipes that have a porous outer surface are partly buried in the rubbish, and pumps draw the biogas into these pipes. The gas is then burnt and used to generate electricity.

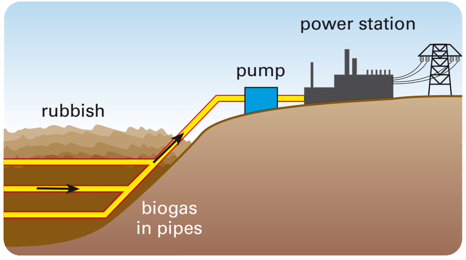



Fig 17 How a biogas power station works

Some processed food manufacturers are using waste peelings to produce biogas. This solves a waste disposal problem as well as producing useful heat energy for the factory. Some sewage treatment plants, eg the one at Luggage Point in Brisbane, use biogas to produce electricity to power the plant. As well as using a renewable energy source, such power plants use up methane, which is one of the gases thought to be contributing to global warming.

## Hydro-electricity

In Australia about 3% of our total electricity is produced from falling water in hydro-electric power stations. However, hydro-electric power stations can only be built in mountainous areas, and there are few suitable sites remaining. Also, the building of storage dams can cause serious damage to the environment by flooding unique habitats. This is why a dam proposed for the Gordon River downstream from the Franklin River in Tasmania was never built.

An advantage of hydro-electric power generation is the ease with which generators can be started up and shut down. It thus provides a convenient and cheap way to supply the additional power needed during peak periods of use. Look at Fig 18. Water from the upper reservoir can be used to produce power during the day when demand is high, and at night when demand is low, the water can be pumped back into the upper reservoir for re-use.

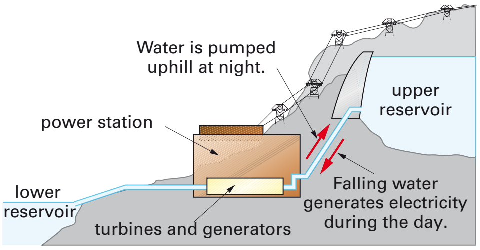



Fig 18 A pumped storage hydro-electric system

## Tidal and wave energy

The tides contain vast amounts of energy, if only we could harness it. To harness the tides, you need to dam off a bay. As the tide comes in, water flows into a reservoir, driving turbines which generate electricity. As the tide goes out, water flows through the turbines in the opposite direction, generating more electricity. However, for this process to work effectively, you need large tides and these occur only in a few places.

The northwest coast of Australia is ideal for power generation because of the large tidal range there. A tidal power station is proposed near Derby, with dams across two arms of a tidal creek and a canal between them. With this design it is possible to generate electricity continuously. However, some people feel that damming the creek will damage the local environment.

### Learning experience

Is hydro-electricity a good alternative energy source for Australia—one of the driest continents on Earth? Should the government continue to invest in this form of energy? Which renewable energy source(s) do the students think Australia should be concentrating its investment in? Why?

Have an open forum for discussion. Students should take notes, as if they were reporters, and then write a newspaper article summarising the discussion. You could divide the class into three groups—the government, scientists, and the Australian community—then get students to write a formal report.

### Learning experience

A fun way to demonstrate the energy stored in biomass is to get the class to build their own compost heap. Choose a sunny, airy position outside and away from classroom windows. Gather materials such as school compost scraps, straw or sugarcane mulch, manure and soil. Build the heap by layering materials, and dampen each layer with water. Tend to the heap over the next few weeks to ensure it is kept moist (not wet). As the matter decomposes, heat is generated. By opening up the heap, students should be able to feel the heat. In a well-decomposing heap, they will see 'steam'.

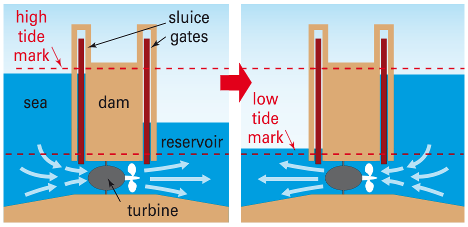



Fig 19 In a tidal power station the turbine can be driven by water flowing either way—from the sea to the reservoir as the tide comes in, and from the reservoir to the sea as the tide goes out.

Ocean waves also have a large amount of energy, as you will know if you have been 'dumped' by a wave. It is possible to use the up and down movement of waves to generate electricity, and scientists have suggested several different ways of doing this. One idea which has been shown to work is shown below. Another idea is to use floats which bob up and down on the waves. These floats would be expensive to build, but may be a possibility in the future. For an animation of these floats, go to www.scienceworld.net.au and follow the links to **The Salter duck**.

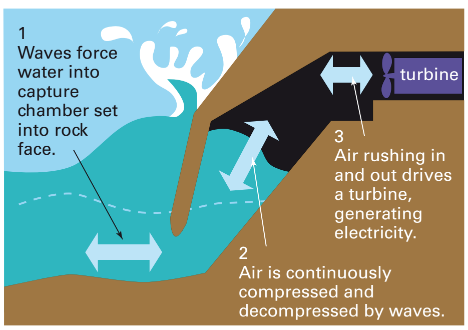



Fig 20 One design for a wave power station

## Geothermal energy

**Geothermal power stations** make use of the heat inside the Earth. In some parts of the world there is a great deal of volcanic action and hot water and steam reaches the surface. New Zealand, Italy, Iceland and the USA have all built geothermal power stations that use this steam to turn turbines and generate electricity. There are no such areas in Australia. However, if holes are drilled down several kilometres, hot granite rocks are found.

This granite contains radioactive elements like uranium and thorium which release heat as they decay. Suitable hot rocks have been found near Innamincka in north-eastern South Australia. The rocks are at a temperature of around 250°C and extend over an area of 1000 square kilometres. The sedimentary rocks on top of the granite act like a blanket, keeping in the heat. There is another smaller region of hot rock near Muswellbrook in New South Wales.

Water is injected into the central borehole and circulated through the hot cracked granite. The heated water is returned to the surface through the outside boreholes. It can then be passed through a heat exchanger where most of its heat can be removed and used to generate electricity. The water can then be returned to the first borehole and used again.

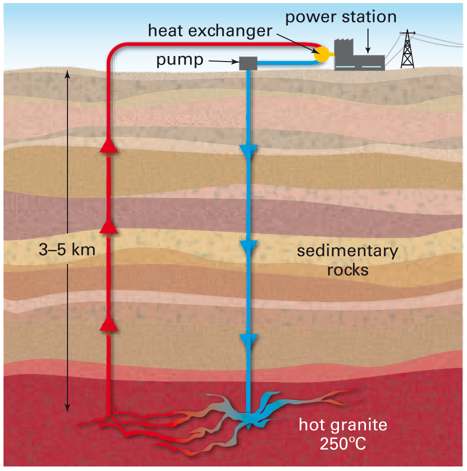



Fig 21 How electricity can be generated from hot rocks. For an animation go to www.scienceworld.net.au and follow the links to **HDR geothermal energy**.

### Hints and tips

Although renewable energy is considered a clean energy source, it is important to explore other factors arising from its use, or how the technology is manufactured, that could impact on the environment. For example, habitat loss or changes to an ecosystem need to be considered, what pollutants are generated in the process of making photovoltaic cells and so on? Do the benefits from using the technology outweigh the disadvantages?

### Learning experience

Students could construct a summary table highlighting the advantages, disadvantages and interesting points about renewable and non-renewable energy sources detailed in this chapter. A way to do this is as a PMI chart. The students need to clearly identify those sources that are renewable and those that are non-renewable. Each energy source could be rated according to its environmentally friendly status, availability and cost.

### Learning experience

On a map of Australia, get students to identify and label where renewable energies are currently being used. They should use a key to identify the type of renewable energy. Students could do this individually or as a class, using a large map pinned up in the room. If you have access to an interactive whiteboard, this could also be an effective tool.

## Activity notes

An alternative activity is for groups of students to perform a role play for the class on a fictitious Australian community that uses only renewable energy (an energy self-sufficient community). They should present their role play in the form of a news item or current affairs program, and consider:

- What renewable energies are used?
- How is it harnessed and supplied to the community?
- Is it cost-effective? Explain.
- Has the community's lifestyle changed? Explain.

Students should consider not only electricity generation but also transport. Are there currently any Australian communities that are energy self-sufficient, or close to it? If so, where are they?

# Activity

## Energy supply proposal

Suppose a mine is to be developed on the Nullarbor Plain in South Australia. Your task is to prepare a proposal for the supply of energy. You will work in small groups, each group representing a different company responding to the notice on the right.

**Step 1: Select an energy system**

Research all the energy alternatives available. Use the information on pages 135–141, but look for more detailed information by going to www.scienceworld.net.au and following the links to these websites.

**Renewable energy (AGO)**
**Sustainability Victoria**
**Renewable energy (NSW)**

To summarise your findings, draw up a table giving advantages, disadvantages and notes for each source.

**Step 2: Collect information**

Collect detailed information on your chosen energy system. Identify the strengths and weaknesses of your energy system, and suggest ways of overcoming any problems (as part of your proposal).

**Step 3: Prepare proposal**

Decide on a name for your energy supply company, and a title for your proposal. Then prepare the proposal for presentation to the group.

**Step 4: Presentation**

Present your proposal (5–10 minutes) on your energy supply system, including arguments for its use. You could prepare a *PowerPoint* presentation. Other students will ask questions about your proposal and try to identify weaknesses in your arguments.

**Step 5: Discussion**

To finish up, have a general discussion of the difficulties of energy supply systems on the Nullarbor Plain. Compare the Nullarbor with your local situation.

### Nullarbor Mine

***Tender for Supply of Energy System***

Manufacturers and suppliers of energy systems are invited to register their interest in tendering for the supply of energy to the proposed uranium mine at Nullarbor. Potential suppliers will be required to provide a general description of their proposed method of energy supply. The proposed method should be cost-effective and suited to the area. The estimated energy requirement for the mine and settlement is 500 megawatts. All proposals must include an environmental impact study.

The Nullarbor mine is approximately 650 km west of Adelaide. The settlement is close to the main highway and about 125 km south of the railway, but it is very expensive to bring in fuel by road, rail or air.

No coal, oil or gas has been found in the area. It hardly ever rains and there are few cloudy days. There are no trees and no streams, but water can be obtained from underground bores.

Nullarbor is close to the ocean, at the top of 80-metre high cliffs. The average difference between high tide and low tide is 1.5 metres. The average wind speed is 8 km/h in summer and 25 km/h in winter, from the west.

## Challenge solutions (page 143)

1 Using the diagram given:
  a There are two reasons for the glass. The first is to act as a greenhouse and trap heat so that it cannot be re-radiated back into the atmosphere. The second is to protect the flat-plate and collecting pipes from the weather and birds.
  b Yes, there might be an advantage in using good-quality Perspex because it might not get broken, eg in a hailstorm.
  c The collector is black because a black surface is a good absorber of radiant energy. This means that it will heat up more quickly in the sun.
  d The movement of the water is a result of convection currents. These currents are caused because colder water is more dense and will flow to the lowest point and push the warmer water upwards.
  e The storage tank is insulated to reduce the loss of heat from the hot water in it.
  f The advantages of having the storage tank inside the house rather than on the roof are that it is more protected from the weather and also that it will lose less heat to the surrounding air (especially at night).
  g In Australia, the sun is usually in the northern part of the sky. If the heater is facing directly north it will have a maximum exposure to the sun as it appears to move across the sky. This will mean that it will work as efficiently as possible.

2 Using the figures given:
  a The solar cells need to produce 2640 MW. To do this at 15% efficiency they need to be exposed to $2640 \times \frac{100}{15} = 17\,600$ MW of solar energy. The area of solar cells required to do this:
  $= \frac{17\,600\,000\,000}{1000}\ \text{m}^2$
  $= 17\,600\,000\ \text{m}^2 = 17.6\ \text{km}^2$

## Check!

1 What energy change takes place in:
  a a solar cell?
  b a solar water heater?

2 What is biogas? What can it be used for?

3 An experimental wave generator can extract 50% of the energy carried in waves. If many similar generators were placed along a 25 km front in waves with a power of 80 kW per metre, what would the total power output be?

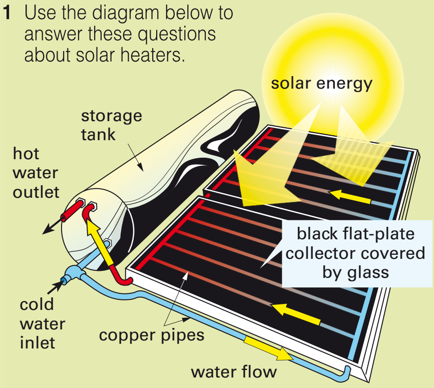
4 What are the similarities and differences between a hydro-electric power station and a tidal power station?

5 A solar water heater costs about $2500 more than an electric or gas hot water system. However, there is a government rebate of $1000. If a solar heater saves 70% of water heating bills, calculate how long it would take for the solar heater to pay for itself. (Assume electric or gas water heating costs are about $350 per year.)

6 Draw a diagram to show how you could generate and collect biogas from household rubbish. What kinds of rubbish would work best?

## challenge

1 Use the diagram below to answer these questions about solar heaters.




  a Why is the collector covered with a glass plate?
  b Would there be any advantage in using a plastic cover instead of a glass one?
  c Why is the collector black?
  d Why does the water move in a cycle from the storage tank to the collector and back to the storage tank?
  e Why is the storage tank insulated?
  f What advantage would there be in having the storage tank inside the house instead of on the roof?
  g Why is the solar heater positioned on the roof so as to face in a northerly direction?

2 A coal-burning power station has a maximum generating capacity of 2640 MW. The average daily rate at which this area receives solar energy is 1000 W/m$^2$.
  a What area of solar cells, operating at 15% efficiency, would produce the same amount of power as the power station?
  b If a typical residential block of land in the city has an area of 750 m$^2$, how many of these blocks does your answer in **a** represent?

3 In 2005 Australia used 140 million litres of oil per day. Crude oil contains about 12% petrol.
  a Calculate the quantity of petrol used every day in Australia in 2005.
  b Alcohol is an excellent fuel which can be produced from sugarcane and other plants. Petrol containing up to 10% ethanol (gasohol) can be used in cars without making any engine modifications. Find the quantity of crude oil that could be saved if all the petrol in Australia was converted to gasohol.
  c If we were to use gasohol instead of petrol we would need to use half our present farmland to grow energy crops like sugarcane. This means new farmland would have to be made by clearing forests. Discuss the pros and cons of this course of action.
  d Suggest why alcohol is not used as a fuel in Australia at present.

4 Explain why the energy in wind and waves is sometimes called 'second-hand solar energy'.

## Check! solutions

1 a In a solar cell, solar energy is converted to electrical energy.
  b In a solar water heater, solar energy is converted to heat energy.

2 Biogas is produced when organic materials are decomposed by microbes. It consists mainly of methane, which can be burned to produce electricity.

3 The total power output can be calculated as follows:
Power = 80 kW/m × 25 000 m × 50%
= 1 000 000 kW
= 1000 MW

4 The similarity is that both depend on the movement of water to turn turbines, which produce electricity. The difference is that for hydro-electricity this movement of water originally depends on the heat from the sun, whereas for the tidal energy it depends on the gravitational pull of the moon. Also, with the hydro-electric power station the movement of water is in one direction only (downward), but is in both directions for a tidal power station.

5 Assuming that electric or gas water heating costs are about $350 a year, a saving of 70% is $245 and reduces this cost to $105. Since the net cost is $1500 to install, it will take 1500/245 = 6.1 yrs to pay for itself.

6 The kinds of rubbish that would work best would be organic materials such as vegetable peel, other food scraps, 'soft' garden waste (eg lawn clippings but not wood) and even faeces from animals like sheep or poultry.

  b If the average housing block is 750 m$^2$, the number of blocks required is:
$$\frac{17\,600\,000}{750} = 23\,467.$$ That is, approximately 23 500 blocks.

3 a The average amount of petrol used daily in Australia is 12% of 140 million litres = 16.8 million litres.
  b If alcohol could be used to replace 10% of this petrol it would save approximately 1.68 million litres of petrol and therefore 14 million litres of crude oil.
  c There are several arguments for and against this idea.

Arguments for gasohol include:
- less atmospheric pollution
- the fact that it is a renewable fuel
- conservation of petroleum supplies
- less dependency on other countries for fossil fuels.

Arguments against gasohol include:
- loss of valuable farming land
- destruction of more rainforest
- increased erosion of topsoil
- increased use of water, and pollution of soil and waterways (eg fertiliser in the rivers).

As with any of these topics, the answer is to compromise and make sure that energy is used wisely and efficiently. This will mean good public transport systems and efficient cities where travel and transport are minimised.

  d Alcohol is not used very much as a fuel because it costs more to produce than petrol. However, this situation may change within a few years.

4 Almost all waves are caused by wind and all wind is caused by the unequal heating of the Earth's surface by the Sun. This causes cooler, denser air to flow towards areas of hotter, less dense air. This is why the energy in wind and waves can be considered to be 'second-hand' solar energy.

5 We presently pay about 17.4 cents per kWh for electricity that is produced mainly in coal-burning power stations. Create a table of costs between now and the year 2020, assuming this cost increases by 5% per year. Then create a table of costs for electricity from solar cells, assuming it costs 50 cents per kWh now and *decreases* by 10% each year.

Plot the two sets of data on the same graph, and predict when solar electricity will be cheaper than power station electricity.

6 Use what you have learnt in this section to decide which type of power generation would be most suitable for a small town of 500 people in each of the following locations. In each case explain your choice.

**a** an Antarctic base

**b** a small Pacific Island

**c** a valley in the mountains of Nepal

7 Is there any energy source that can be used without any environmental impact? Discuss this in a group.

## try this

Your task is to design and construct one of the following:

- a solar water heater that will increase the temperature of about 4 litres of cold water by at least 20°C after standing in sunlight for one hour, or
- a wind or wave generator that will generate a small electric current.

Use these steps in your construction:

1 Use the diagrams on the right for ideas. Search for other ideas in the library or on the internet, and discuss the task with other people.

2 Draw a plan of your device before you start. List the materials and equipment you will need. You may need to ask your teacher for help.

3 Build a *prototype*—your first experimental model.

4 Test your prototype and make any necessary modifications. Then test your modified model.

5 Demonstrate your design to the rest of the class. Then prepare a written report, saying what you did, how successful your model was, and giving suggestions for improvements. (Your model may be good enough to enter in a science contest.)

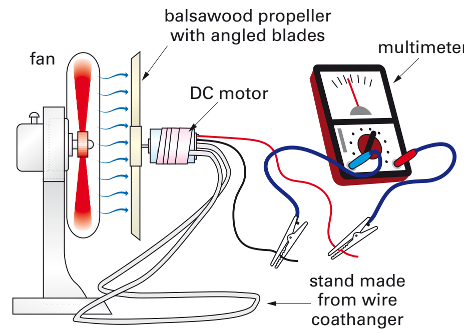



**Fig 24** A wind generator

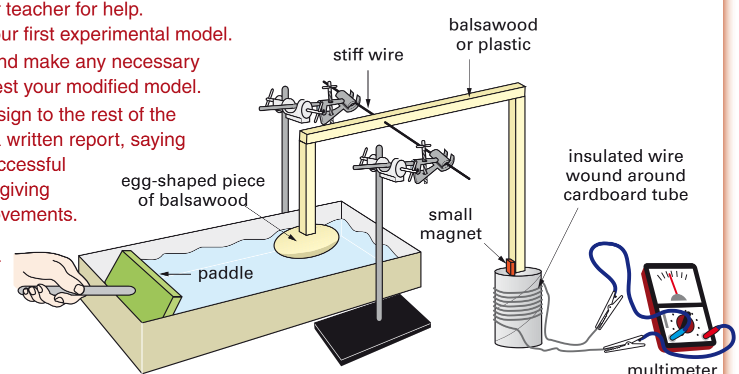
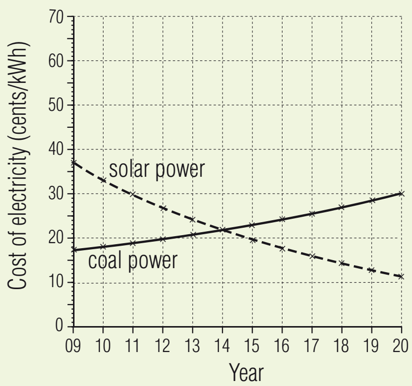



**Fig 25** A wave generator

**Teacher note:**
You will need to do this outdoors.

5 You will need a calculator to work this out.

| | *COAL* | *SOLAR* |
|---|---|---|
| *Year* | *cents/kWh* | *cents/kWh* |
| 2009 | 17.4 | 36.5 |
| 2010 | 18.2 | 32.8 |
| 2011 | 19.1 | 29.5 |
| 2012 | 20.1 | 26.8 |
| 2013 | 21.1 | 23.9 |
| 2014 | 22.2 | 21.5 |
| 2015 | 23.3 | 19.4 |
| 2016 | 24.4 | 17.4 |
| 2017 | 25.7 | 15.7 |
| 2018 | 26.9 | 14.1 |
| 2019 | 28.3 | 12.7 |
| 2020 | 29.7 | 11.4 |




This data and graph enable you to predict that costs will be approximately equal in the year 2014 and, after that, solar will be cheaper.

6 Recommended power generation would be as follows.

a Antarctica is renowned for persistent high-speed winds, which would ideally suit wind generators. Of course, some batteries would need to be used for storage and some precautions might be necessary to prevent the blades 'icing up'.

b A small Pacific island is likely to have little wind, tidal movement or geothermal activity. It is not feasible to build a power station for fewer than 500 people. The method that would probably be most suitable to produce electricity would be solar panels together with storage batteries.

c A valley in Nepal is very likely to have flowing water, hence, small hydro-electric generators would be ideal. An alternative would be necessary in the winter if the water freezes into ice.

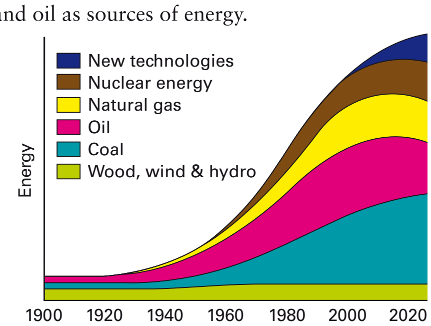
7 The short answer is no—all sources of energy will have some environmental impact. Even solar panels attached to a space station have to be manufactured and will have some impact on Earth. Possibly, wind generators and solar panels might cause the least impact. However, even some alternative energy sources, eg tidal power, might cause restricted movement of water in a bay and cause environmental problems.

### Hints and tips

'Try this' is a good extension activity but has the potential to make a mess, so it is better done outside. With the fan model it is possible to do a calculation of efficiency, and even experiment with different blade materials and designs.

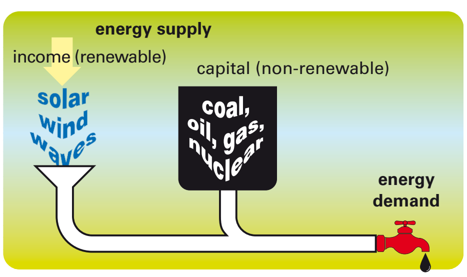
# 6.3 Managing energy

As the graph below shows, the world's use of energy has changed greatly over time. Combustion of wood was the main method of obtaining energy before 1900. Wood supplies once seemed inexhaustible and, like fossil fuels, satisfied most of the demands of the time. The clearing of forests and an increasing demand for a cheaper and more convenient fuel to operate machines led to the change from wood to coal and oil as sources of energy.




Non-renewable fossil fuels are our *energy capital*—like money in the bank waiting to be used. But once used, these resources are gone forever. On the other hand, the Sun's energy is supplied continuously. So is the energy of the wind and tides. These renewable resources will always be available. They are our *energy income*—like money from a permanent job.

Almost half of the world's energy needs are presently met by oil, but world oil supplies are predicted to run out in about 40 years time. This is like having a large tank of fuel which you keep using. Eventually the tank will be empty! Demand cannot be greater than supply for any great length of time. Our energy capital is shrinking and cannot be renewed. However, we can decrease our energy demand by using less of our energy capital, and we can use more of our renewable energy income. At present most of this renewable energy is not used.




We do not yet know the best mix of energy resources for the future. However, it is clear that to slow down global warming and to reduce air pollution, there must be a significant reduction in fossil fuel combustion. Obviously we need to save energy where possible, and use energy more efficiently. We also need to make greater use of renewable energy sources.

## Saving energy

There are many ways in which you as an individual can cut down on energy wastage. Below are a few ideas. For more ideas go to www.scienceworld.net.au and follow the links to **Global Warming—Cool It**.

### Transport

About 40% of the energy used in Australia is used for transportation. So if we are to cut down on our usage of energy, we must cut down on the use of petrol for cars, diesel for trucks and kerosene for aircraft.

To get from one place to another requires energy. The table lists the amounts of energy needed for various methods of transport. Cycling and walking are by far the most efficient ways of travelling; travelling by car or by plane is very inefficient in terms of energy use.

| Energy needed per person per kilometre ($10^6$ joules) | |
|---|---|
| cycling | 39 |
| walking | 54 |
| by train | 390 |
| by bus | 480 |
| by car | 1350 |
| by plane | 1890 |

## Hints and tips

- Renewable energy is currently a hot scientific and political topic. Talk to the students about the Mandatory Renewable Energy Target (MRET). It is proposed that by 2020, 20% of Australia's energy should be generated from renewable sources. Do the students think this will be achieved? How?
- Climate change and the hole in the ozone layer are quite different problems, so make sure students don't confuse them. The hole in the ozone layer is caused by chemicals combining with the ozone in our atmosphere, leaving less ozone to block out harmful types of radiation from the sun. While some gases, such as chlorofluorocarbons (CFCs), deplete the ozone layer and also add to climate change, most greenhouse gases that cause climate change do not affect the ozone layer.

## Learning experience

In February 2008, the Wilkins Ice Shelf of Antarctica began to break up. Ask the students to investigate why scientists believe this has occurred, what the impact of this might be and what it suggests about climate change.

## Learning experience

The internet can provide stimulating interactive tools/resources for students to investigate. The BBC Science & Nature website has a very good Climate Challenge game. Students take on the role of president of the European Nations. They have to tackle climate change and stay popular enough with voters to remain in office. Once the students catch on to how it is played, they will become so absorbed that they won't want to exit! Further details can be found in the *ScienceWorld 3* Webwatch for Chapter 6. Follow the links to 'Climate Challenge game'.

## Learning experience

If all the icebergs in the ocean melted, what might happen to the sea level?

- Place a large beaker on a white surface and fill it with ice cubes.
- Fill the beaker with coloured water (quite a few drops of food dye), being careful not to spill any.
- Ensure all the ice cubes are floating and not resting on the bottom of the beaker. Some cubes should be floating above the rim of the beaker.
- Ask students to predict what will happen when the ice cubes start to melt (this takes about 20 minutes). Most will probably predict the water will overflow the beaker. You will know if this has happened if any coloured water ends up on the white surface. Condensation will drip onto the white surface but no coloured water.

Discuss with students how global warming may melt floating icebergs. Will this contribute to a rise in sea level? Land ice will also melt. Will this contribute to a rise in sea level?

### Hints and tips

In 2008, there were three hybrid cars available in Australia—the Toyota Prius, the Honda Civic Hybrid and the Lexus (several models). How cost-effective are they? Students could draw a schematic diagram to illustrate how a hybrid car operates.

### Homework

Have students do some reflective thinking about this chapter so far. Write the following questions out as a worksheet for the students to take home:

1. What do you think is the most important point that you have learned in this chapter so far?
2. How has your thinking about this topic changed from the start of the chapter?
3. What is the most interesting thing you have learned?
4. What do you feel most confident/least confident about in relation to this chapter?
5. How well do you think you have worked with other people?
6. What is one thing you can do to improve your learning?

Don't grade this work, as it is mainly students' reflections.

Many people prefer to travel to work or school by car. However, large numbers of cars in cities use huge amounts of petrol and also cause air pollution. For this reason people are being encouraged to use public transport. For example, you can travel by car or bicycle to the nearest railway station, and then travel into the city by train.

Our present petrol cars are only about 25% efficient. In other words, for every 100 joules of petrol you put in the tank, you get only about 25 joules of kinetic energy (Fig 28). However, there are other ways of powering cars. One of the most likely possibilities so far is the electric car. It is quiet, produces very little pollution, and has an efficiency of about 70%. The electricity for electric cars would probably come from coal, thus cutting down our use of oil.

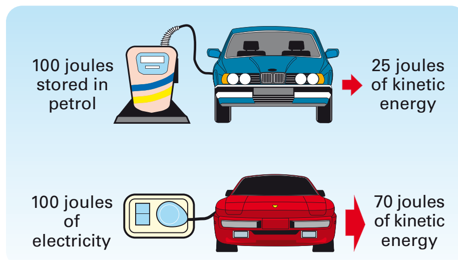


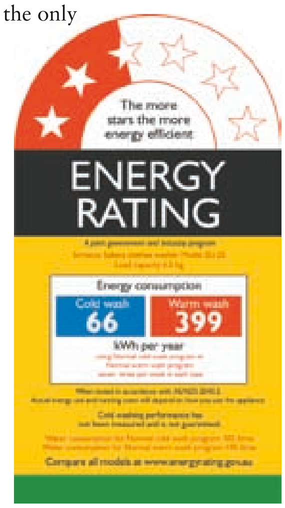

**Fig 28** Battery-powered electric cars are more efficient than petrol-powered cars.

At present electric vehicles have a limited range. This means you cannot go far without recharging the batteries. What is needed is a better battery than the present lead storage battery, and much research is being done on this. However, hybrid electric vehicles are already available in Australia, eg Honda's Civic and Toyota's Prius. They have a petrol engine *and* an electric motor.

There are things which can be done to conserve petrol. Here are some of them.

- If possible, use a small car.
- Reduce your cruising speed. Reducing speed from 110 km/h to 90 km/h cuts fuel consumption by up to 25%.
- Share a car with a friend.
- Keep the engine properly tuned, eg check spark plugs regularly.
- Use good tyres, properly inflated.
- Keep well behind other cars, so that you do not need to brake when they do.

## Electrical appliances




In prehistoric times the only energy available to humans came from the stored energy in the food they ate, and from their fires. We now have many electrical appliances to make life easier. Many of these have an energy label which tells you how efficient they are and how much energy they use.

You could probably do without some electrical appliances. There are also many things you can do to cut down on the energy used by the appliances you do have. Here are some suggestions:

- Turn lights off when you don't need them.
- Fluorescent tubes are more economical than ordinary light bulbs, except when they are turned on and off frequently.
- If you have an airconditioner, set the thermostat no higher than 21°C during winter and no lower than 23°C in summer.
- Use the Sun to dry your clothes, rather than a clothes drier.
- Switch off the television when nobody is watching it.
- Keep the refrigerator door shut as much as possible.
- Use an extra blanket or doona instead of an electric blanket.
- Use only small amounts of water when cooking.

### Learning experience

How energy-efficient are cars today compared with those manufactured 50 years ago? Have students look through car magazines or other resources to find designs and features that make cars more fuel-efficient and environmentally friendly. What models of cars are currently being marketed that claim to be the most fuel-efficient and environmentally friendly? To present their information, students could make their own car advertisement.

- Fix dripping hot-water taps quickly.
- Do not iron sheets and other items which do not really need it.

Fig 30 Low-energy light bulbs cost more but use less energy and last longer.

## House design

In Australia about 15% of our total energy use is in the home. The amount of energy used for lighting, cooking and appliances is much the same throughout Australia, but the amount used for heating and cooling varies with the climate. Water heating costs can be reduced by using a solar water heater. Heating and cooling costs can be reduced by the design of the house and by insulation.

In Australia the Sun moves across the northern sky and is lower in winter than in summer. For this reason it is suggested that homes be built with the living areas facing north, so that the Sun will warm them in winter, thus reducing heating costs. Shading devices are needed in summer to stop the sunlight from reaching the windows. Deciduous trees planted close to the house also block the heat from the Sun in summer.

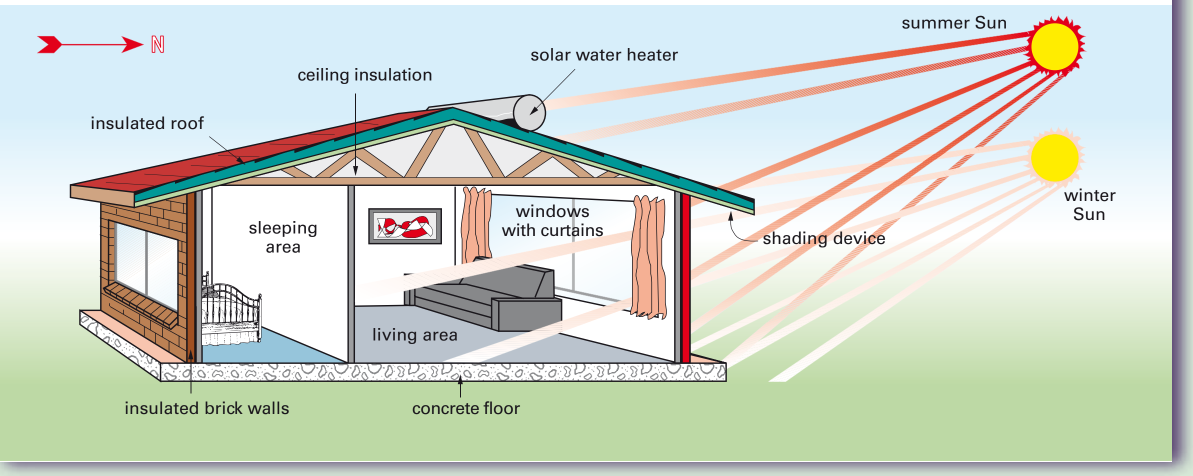
Insulation in the walls reduces heat loss during winter and heat gain during summer.

## Activity

In a group discuss the suggestions on this page and the previous page for saving energy at home and when travelling.

- Which of the things suggested are you already doing?
- Brainstorm other things you could do to save energy.
- What factors might prevent you from implementing some of these energy-saving ideas? (For example, why don't you change to a solar hot water system?)

Fig 31 A house designed to reduce heating and cooling costs




### Hints and tips

Spend about five minutes reviewing the chapter so far. You could run an open-book quiz or another true/false quiz.

### Activity notes

As an extension activity, students could do a home energy audit. They should check each room in their home and list appliances/items that use energy and decide how efficient they are.

- If the item has an energy star rating, make a note of it.
- Do all rooms have low-energy light bulbs?
- Are there water-saving features installed?
- Are appliances turned off at the power point rather than being left on standby?
- What conclusions can students make from their audit?
- What changes could their household make to reduce energy consumption?
- Is there a particular room or person that uses more energy?

Students could write a plan for their household and discuss with them ways to reduce energy usage.

### Learning experience

Have students compile a list of ways to save energy at school and home. They could present the information as a flyer to be photocopied and put into the school newsletter. If an electronic medium is chosen, the presentation needs to be visually stimulating enough to put on the school's website. Encourage practicality, clarity and creativity.

### Learning experience

Students could draw a design of the place they live in and write down good and bad points about its features in relation to energy efficiency. What modifications could be made to improve the design? Students could find out more about designing energy-efficient houses.

### Learning experience

Organise for an architect to visit the class and give a presentation about energy-efficient design. Also ask them to talk about their work and the type of science they use. All new houses built have to have an energy rating. Ask the architect to explain what this means.

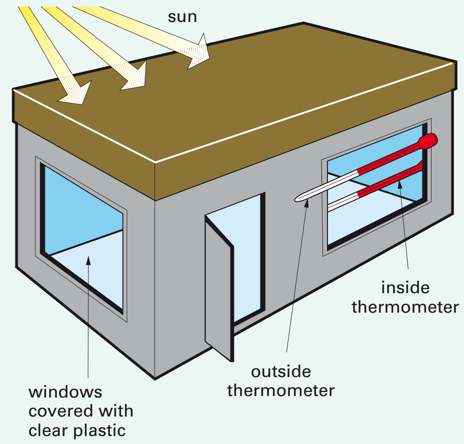
## Lab notes

- Packing boxes for computers or photocopy paper are ideal for constructing the model houses.
- If enough equipment is available, different groups can test different variables, as suggested in Try this.
- It is ideal if the experiment can be set up outside the classroom overnight.
- This activity is very suitable for datalogger use. The ability to sample data every few minutes for 24 hours or so is highly preferable and very meaningful.
- It is a good idea to have the datalogger/computer inside and run extension leads for the sensors under a door. Such low-voltage extension leads can be made easily and safely from electrical extension cords.
- A timer for the light/heat source could simulate different day lengths when operating indoors. It may be worth purchasing a hydroponics light source from a specialist gardening centre. They are very effective for school use, especially where the climate is unreliable.

# Experiment
## A MODEL HOUSE

### Your task

To design a model house to test the effectiveness of insulation.




### Planning and Safety Check

Read through the Method ideas and work out a plan for your experiment. If you are going to do it over 24 hours you will need a safe place to leave the equipment set up.

### Materials

- shoebox or similar box with lid
- scissors
- clear plastic (for windows)
- 2 thermometers or temperature probes and datalogger
- insulation materials, eg corrugated cardboard, styrofoam, aluminium foil, woollen cloth

### Method ideas

1. Use the shoebox (or other box) to make a model house similar to the one in the diagram. Make sure the house has:
   - a window covered in clear plastic in each wall, and a door
   - a well-fitting roof
   - one thermometer on the outside and one on the inside that can be read without removing the roof.
2. To heat the house, place it in the sun or near an electric heater or high-wattage light bulb.

   How often should you record temperatures?
3. To test the effectiveness of insulation you will need to do the experiment with and without insulation and compare the results.

### Discussion

1. Which are the independent and dependent variables in this experiment? Which variables did you control?
2. Write a brief report on the effectiveness of insulating the model house.
3. Compare your results with those of other groups. Which is the best insulating material?
4. Suggest reasons for any unusual results.
5. Evaluate your experiment and suggest ways of improving it.

### try this

You could extend your experiment into a project by investigating some of these questions:

- How quickly does the house cool after the Sun sets?
- Does the thickness of the insulation make any difference?
- Do curtains on the windows make any difference?
- What effect does an overhang (eaves) on the roof have?
- What difference does altering the number of windows and their position have?
- Does the type of roofing material make any difference?

## The electricity grid

Electricity is a convenient form of energy because it can be transmitted from one place to another, it can be switched on and off, and it can be used as a source of power for many different appliances. In Australia and in most countries our lifestyle has come to depend on electricity.

Power stations produce this electricity, which is transmitted to our homes and to industry via a vast network of mostly overhead cables called the *electricity grid*. All the power stations in the state are inter-connected, and if there is not enough electricity in one part of the grid it can be obtained from another part. Similarly, excess electricity can be fed into the grid and used elsewhere. Electricity generated using renewable energy sources such as solar cells, wind generators and biomass can also be fed into the grid.

Instead of connecting to the electricity grid, it is possible to be energy self-sufficient using a system called Remote Area Power Supply (RAPS). In a typical RAPS system, electricity is generated by solar cells and a wind generator. There is also a backup generator and batteries to store electricity.

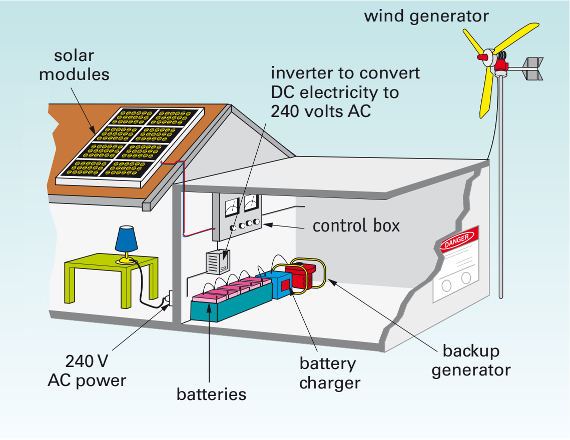



**Fig 33** A Remote Area Power Supply (RAPS) can be used in towns and cities, as well as in remote areas where it is not possible to be connected to the electricity grid.

### Hydrogen—fuel of the future

Take an imaginary journey into the future.

*It is the year 2100, in the middle of a busy city. The traffic is remarkably quiet and there are no smelly exhaust fumes. Most of the cars, trucks and buses are using hydrogen fuel and produce little more than harmless water vapour. There are no electric power lines and no chimneys spewing tonnes of harmful gases into the atmosphere. As you move into the industrial area you notice a row of large storage tanks. These store liquid hydrogen which is piped into the city and used for transportation, heating, cooling and electricity. You travel to the country and find huge solar panels and wind farms generating electricity to produce the hydrogen.*

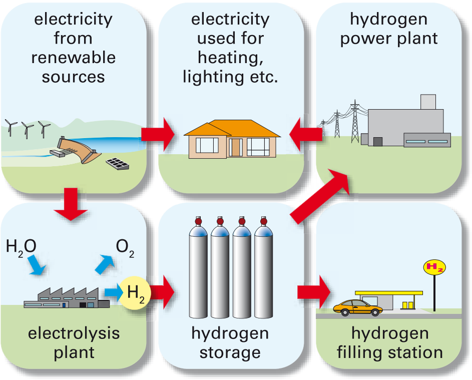



**Fig 34** A possible hydrogen energy system—for an animation of this, go to www.scienceworld.net.au and follow the links to **miniHydrogen**.

This science fiction may come true in the future. Most of the technology already exists, but there are many obstacles to be overcome—mainly cost. Hydrogen is an ideal fuel. It can be made from water by electrolysis—passing an electric current through it.

$$2H_2O + \text{ENERGY} \rightarrow 2H_2 + O_2$$

Making hydrogen this way uses up more energy than the gas gives up when it burns in oxygen. However, this problem could be overcome by

### Hints and tips

The miniHydrogen animation, found in the *ScienceWorld 3* Webwatch for Chapter 6, is well worth getting the class to do. Consider showing it through a data projector so you can stop it at any point to explain technical terms or answer any questions students might have.

### Learning experience

When natural disasters occur, such as cyclones or storms, the electricity supply is sometimes disrupted for lengthy periods. How do you think a community that is self-sufficient would cope if this happened to them? What protective mechanisms and infrastructure need to be put in place and why? Have students investigate these questions as a Think/Pair/Share activity (see Starting point, page 25).

### Learning experience

Iceland, where renewable resources supply 70% of the country's energy needs, is considered to be at the forefront of renewable energy research. Iceland proposes to become the world's first hydrogen economy. Just about all transport will use hydrogen, making it the first completely energy-independent country in the world. What can other countries learn from Iceland? What implications would there be for Australia if we decided to do the same? Have the students find out more about using hydrogen as a fuel.

### Hints and tips

Solving one problem using science can sometimes cause many more problems. It is important to remind students that *science cannot provide all the answers*.

### Research

Ask students to research a scientist at work in a field related to this chapter, eg meteorologist, architect, automotive engineer, environmental scientist, and so on. Have students ask questions about the scientist's work, and their views and perspectives about our energy future.

- How aware does the scientist think the public and government are?
- How committed is the scientist to changing our views about the energy crisis?
- What is their viewpoint about the energy crisis: is there too much fuss and not enough action, not enough fuss, or does the balance seem right?

Students could present a written report or audio file as a series of questions and answers.

### Issues

*What does our energy future hold?* Climatologists say we need a 'science and technology climate control mission' that has the same vigour as the 'moon mission' of the 1960s. They suggest that 'a vision is needed to solve the known unknowns'.

In groups, get the students to discuss the issues surrounding these statements and present their ideas to the class. An issues map could be a useful tool for the students to begin their discussion.

making the hydrogen using renewable energy sources such as solar cells. Scientists are also experimenting with other ways of making hydrogen. For example, certain photosynthetic microbes produce hydrogen using light energy. The hydrogen can be used directly as a fuel or it can be used to generate electricity using **fuel cells**.

$$2H_2 + O_2 \rightarrow 2H_2O + \text{ENERGY}$$

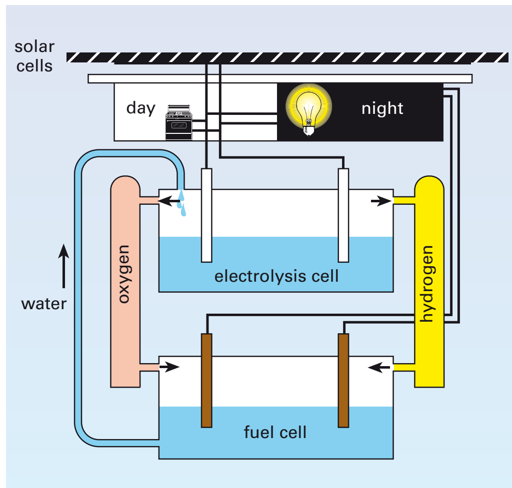



**Fig 35** This system overcomes the problem of solar cells only producing electricity during the day. Some of the electricity generated during the day by solar cells is used to electrolyse water into hydrogen and oxygen. At night the hydrogen and oxygen are recombined in a fuel cell to produce electricity.

Two big advantages of hydrogen are that it can store energy and it is easily transportable. It can be liquefied and used as a motor fuel in the same way that LPG is used now. One problem with hydrogen is that it is flammable. This problem, however, can be overcome using a storage tank containing fine particles of a metal alloy that absorbs hydrogen like a sponge, forming a compound known as a metal hydride. Heating the tank releases the hydrogen gas slowly and safely.

## Our energy future

We seem to use energy as though it were unlimited. We buy more and more electrical gadgets: high-rise office blocks are airconditioned all year round, with windows that do not open; city lights blaze all night; we drive to the corner shop instead of walking; and so on. We just seem to take energy for granted. However, our energy reserves are very limited—especially oil, from which we get petrol for our cars. Fossil fuels will one day be exhausted, and alternative energy sources will have to be developed to replace them.

Many alternative sources such as wind and solar are being used to supplement our power needs, and scientists and engineers will no doubt develop new ways of harnessing energy. But *science cannot provide all the answers*. Before we use new energy sources we must consider any possible environmental problems they might cause. Different sources of energy have different problems, and no energy source is trouble free. We must choose wisely from the alternatives. Energy is a very valuable resource. Without it we could not live as we do now.

### Activity

Electricity from renewable sources such as solar, wind and biomass is at present more expensive than from non-renewable sources such as coal-burning power stations. Most energy supply companies will buy renewable energy if you pay them $3–4 extra per week. This not only conserves our reserves of non-renewable energy but also cuts down on greenhouse gas emissions.

- Suggest why energy from renewable sources is called *green power*.
- Do you think you would pay extra for green power? Explain.
- At present only 1% of people are paying extra for green power. What would need to be done to get more people to switch to green power?

### Activity notes

What is green power? Students could design a brochure to explain what it is, why it is called green power/energy, its availability, who supplies it, how it is generated and any other relevant information. See if the students can find out what green energy is available in the area where they live. Does their household already use it? The intended audience for the brochure is Australian families.

## Science in action

### Light up the world

Dave Irving-Halliday is an electrical engineer at the University of Calgary in Canada. In 1997 he was trekking in Nepal when he saw a sign outside a schoolhouse in a small village inviting people to stop and help teach the children. He went inside and was shocked to find the students working in semi-darkness. His first thought was *Gosh, it's dark in here*, followed by *I wonder if I can help them?*

As Dave travelled back to Canada he was thinking about the challenge of lighting homes in remote villages around the world. He realised that he would have to come up with a system that was extremely cheap and reliable. He had an important thought—*Why light a whole house, when you only need light in certain areas?* He decided to investigate light-emitting diodes (see page 82). These were invented in the 1960s and were gradually becoming brighter and more efficient. They could also last for 30 or 40 years. However, because they emitted only coloured light, they were unsuitable for domestic lighting.

After a year trying to develop his own white LEDs, Dave was surfing the web when he found that a Japanese company called Nichia had already solved the problem. When he got hold of one of these new white LEDs, he exclaimed to his assistant *Good God, John. A child could read by the light of a single diode!* So he set up a foundation called 'Light up the World' and began developing a multi-diode lamp to light homes in Nepal. He also developed a simple pedal generator and a small wind turbine to power the lamps. He returned to Nepal in 2000, where he teamed up with another engineer, Stewart Craine, from the University of Melbourne, who had been working with Australian Volunteers International.

Today Dave's lamps can provide limited lighting for a Nepalese village of 60 households for the same amount of energy as a single 100-watt lightbulb in one room of an Australian home. The lamps have also spread to India, Sri Lanka, Africa and South America. A father of five in a Sri Lankan village said, *This is the first time in the lives of my children that they have been able to read at night.*


**Fig 36** Dave Irving-Halliday with his lamps, outside a village in Sri Lanka

Dave set up a company called Pico Power Nepal in Kathmandu. It manufactures lighting systems and sells them at affordable prices to the villagers. Nepalese households spend half their $330 annual income on batteries for torches and kerosene for lamps. So with the new lamps, they don't need as much kerosene, and the use of rechargeable batteries means fewer used batteries are thrown away.

For the first five years the Light up the World Foundation was funded entirely by Dave and his wife, but lately people around the world have supported the foundation with donations.

#### *Questions*

1 Why can't normal lights be used in Nepalese villages?
2 What was the scientific breakthrough that enabled Dave to fulfil his dream to 'light up the world'?
3 What provided the power for Dave's white LED lamps?
4 In what way is the white LED lamp good for the environment of developing countries like Nepal?
5 What lessons can we in Australia learn from this story?

### *Hints and tips*

Asking students to read this article aloud not only keeps them focused but assists those who have a preference for auditory learning. A teacher can gain insights into the learning abilities of students by observing how well they can read. However, be careful not to choose a reader who you know has a language disorder, unless they are willing to read.

### *Learning experience*

Teach the students some methods to summarise an article. An effective way is to photocopy the page and get students to use a highlighter to mark key sentences in each paragraph. These sentences can then form a summary.

### *Learning experience*

Revise the concepts taught in this chapter by asking the students to make their own true/false quiz with answers. The quiz questions can be asked in small groups or as a class.

## Check!

1 Answer the true–false questions in the Getting Started on page 127 again. Have any of your answers changed?

2 How do the following help conserve energy and reduce greenhouse gas emissions?
- a wearing a jumper inside the house on cool nights
- b using lids on pots when cooking vegetables
- c using public transport instead of your own car
- d recycling cans, bottles and paper
- e using only small amounts of water when cooking
- f repairing things that break down instead of replacing them

3 In a group discuss the advantages and disadvantages of the RAPS system in Fig 33 on page 149.

4 This sign was painted on the side of an experimental vehicle which used an alternative fuel: $2H_2 + O_2$ = NO Smog
- a Suggest what the fuel was.
- b Explain what you think the sign means.

5 Write down a list of electrical appliances that you use which you feel are:
- a essential to your present lifestyle
- b not essential to your present lifestyle.

6 Assuming that each kilowatt-hour of electricity produces about 1.2 kg of $CO_2$, check your family's electricity bills and determine how much carbon dioxide your family produces each year.

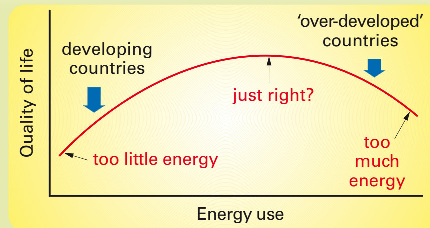
7 Use the internet to research fuel cells and hydrogen cars.

## challenge

1 Use the graph on page 145 to answer these questions.
- a Calculate the proportion that each energy source contributes to the world's present energy use.
- b How are these proportions expected to change by the year 2020?
- c Which energy source would you expect to make up the greatest proportion in the year 2050? Explain your answer.
- d Use the graph to predict when the world reserves of oil will run out.

2 Write a story describing what could happen if we don't manage our energy resources wisely.

3 The graph on the right relates quality of life to the amount of energy used by different countries.
- a What does 'quality of life' on the vertical axis mean?
- b Give an example of a developing country.
- c Would you say that Australia is an 'over-developed' country? Explain.
- d Explain what the graph tells you.




4 You are trying to decide which type of lights to put in your new home. The table gives technical data for five different types of household lights which produce about the same amount of light.

| Type of lighting | Unit cost | Lifetime (hours) | Power (watts) |
|---|---|---|---|
| incandescent globe | $1 | 1000 | 60 |
| fluorescent tube | $4 | 5000 | 40 |
| compact fluorescent | $10 | 8000 | 15 |

If the cost of electricity is 15 cents per kWh, which type of lighting would be the cheapest to run over 8000 hours? (Hint: take into account the running costs and cost of replacement bulbs/tubes.)

## Check! solutions

1 The correct answers are:

| | | | |
|---|---|---|---|
| 1 | false | 9 | true |
| 2 | true | 10 | true |
| 3 | true | 11 | false |
| 4 | true | 12 | false |
| 5 | true | 13 | false |
| 6 | false | 14 | true |
| 7 | false | 15 | true |
| 8 | true | | |

2 a Wearing a jumper will keep you warm and reduce the need for heating the house.
- b Using a lid will keep the steam and the heat in the saucepan and save heat energy.
- c A bus or train that can carry many people is more energy-efficient than a car, which carries only one or two people.
- d Recycling these materials usually means that less energy is required to process raw materials into products.
- e It is only necessary to cover vegetables with water when cooking. It is of no advantage to have extra water because this only wastes heat energy.
- f It is wasteful to dispose of an item if it can be repaired. It is a waste of money and also energy because energy is required to manufacture a new item.

3 RAPS is an acronym for 'Remote Area Power Supply'.

Advantages of RAPS include:
- self-sufficiency in case of 'blackouts'
- less energy lost in transmission
- less damage to the environment
- no need to pay for electricity.

Disadvantages of RAPS include:
- dependence on weather conditions for power output
- high cost of buying the equipment initially
- some maintenance costs.

4 a The fuel was hydrogen gas.
- b The sign means that if this fuel is used there is no smog or air pollution. This is true because the product formed when hydrogen burns with oxygen is water ($H_2O$).

5 Answers will depend on particular lifestyles, but remember that some people have lived and can live comfortably without electricity at all.
- a Appliances you might consider to be essential include the refrigerator, stove, lights, heaters, kettle and toaster.
- b Appliances you might consider not to be essential could include the television, microwave, hair dryer, electric blanket, milkshake maker, CD player, computer and telephone.

6 Assuming that your family has an electricity bill for 8000 kWh each year, the amount of carbon dioxide can be calculated as follows:

$8000 \times 1.2 = 9600$ kg $= 9.6$ tonnes

7 One very useful site you can use is <www.science.org.au/nova>. You will find that hydrogen is an excellent fuel because it can be produced by passing electricity through water and produces only water vapour when it burns. One disadvantage is that hydrogen is a gas and has to be compressed for transportation. It will also explode with oxygen and will have to be burned in fuel cells. There are many types of fuel cells being used at present and others are being developed. There are many experimental hydrogen-powered vehicles on the road at present and there will be many more in the future.

MAIN IDEAS

**Copy and complete these statements to make a summary of this chapter. The missing words are on the right.**

1 Most of our present energy sources (coal, _____ and natural gas) are _____ and will be used up in the near future.

2 Nuclear reactors do not cause air pollution, but have two major problems: the possibility of reactor _____ and the disposal of _____ wastes.

3 Solar energy can be converted to electricity in solar cells and to _____ in solar water heaters and solar power stations.

4 Some _____ sources of energy are solar, hydro-electricity, wind, tides, waves, geothermal and _____.

5 Renewable energy sources will have to be used more widely to keep up with the world demand for energy and to reduce _____ emissions.

6 Some ways in which we can save energy are:
- use smaller cars or share cars,
- use _____ rather than private cars,
- _____ our homes
- reduce our use of _____ wherever possible.

accidents
biomass
electricity
greenhouse gas
heat
insulate
non-renewable
oil
public transport
radioactive
renewable

Try doing the Chapter 6 crossword on the CD. Working with technology

REVIEW

1 Which one of the following is a non-renewable energy source?
**A** solar energy
**B** tidal energy
**C** coal
**D** wood

2 The main advantage of solar energy over other energy sources is that it:
**A** is unlimited.
**B** can be converted into heat energy.
**C** can be converted into electrical energy.
**D** can be used only during the day.

3 At a particular place at midday the power of the sunlight is about 500 watts per square metre. This energy can be converted to electricity using solar cells which are about 10% efficient.

To run a one kilowatt electric motor, the area of solar cells required (square metres) would be:
**A** 2 **C** 50
**B** 20 **D** 500

4 The devices listed below all generate electricity from a source of energy.
**a** solar cell
**b** coal-burning power station
**c** wind generator
**d** hydro-electric power station
**e** geothermal power station

For each device, select the appropriate source from the following:

heat energy, potential energy, chemical energy, light energy, kinetic energy, nuclear energy

## Challenge solutions

1 Using the graph on page 145:
 a The proportions are: coal 32%, oil 30%, natural gas 20%, nuclear 11%, and wood, wind and hydro-electricity 7%.
 b There are two major changes you would expect by the year 2020. They are that the amount of oil being used will decrease by about 10% and that the 'new technologies' will increase by about the same amount.
 c By copying the graph and continuing the curves (extrapolating), you can predict that in the year 2050 the biggest energy source will probably be the new technologies. The reason is that currently all the other energy sources are either decreasing or showing signs of stabilising.
 d By continuing the curve (extrapolating), you can predict that, unless there are major new discoveries, oil will probably run out by approximately the year 2050.

2 It is inevitable that as the world's population increases and the standard of living in many countries improves, more and more energy will be required. If energy resources are not managed wisely they will become more and more expensive and available only to the rich individuals and nations. This will create conflict between individuals and nations, which will further deplete these resources.

3 a Quality of life means how much people are able to enjoy their lives. It is different for different people, but includes such things as comfortable homes, health, clean air and water, and being part of a 'family' group. It does not mean quite the same as standard of living.
 b A 'developing country' is one that does not yet have a lot of factories or motor cars. Examples include many African countries, Papua New Guinea, Indonesia and Vietnam.
 c You could argue either way about this. It really depends on which countries you are comparing Australia with. There are certainly ways in which Australians waste energy and most people could live quite comfortably using less energy. For these reasons you could say that Australia, along with the USA and European countries, is 'over-developed'.
 d The graph tells you that the quality of life is not necessarily better just because more energy is used. The graph indicates that some people in some countries use more energy than they need to and their quality of life does not improve.

4 The cost of operating these different lights is made up of the initial purchase costs and the amount of electricity used for 8000 hours, as calculated below for the fluorescent tube. If one tube lasts 5000 hours, then for 8000 hours you will need two, which cost \$8. For the fluorescent tube the amount of electricity used is: 40/1000 × 8000 = 320 kWh. The cost of electricity is: 320 kWh × 15/100 = \$48. Therefore, the total cost for fluorescent tubes is \$8 + \$48 = \$56. The table below shows the costs for all three types of lighting.

| *Type of lighting* | *Cost for 8000 hours (1 kWh = 15c)* | *Cost of globes* | *Total cost* |
|---|---|---|---|
| Globe | \$72.00 | \$8 | \$80.00 |
| Fluoro tube | \$48.00 | \$8 | \$56.00 |
| Compact fluoro | \$18.00 | \$10 | \$28.00 |

From this table it can be seen that the cheapest type of lighting is the compact fluorescent light.

## Main ideas solutions

**1** oil, non-renewable
**2** accidents, radioactive
**3** heat
**4** renewable, biomass
**5** greenhouse gas
**6** public transport, insulate, electricity

## Review solutions

**1** C
**2** A
**3** B

power of sunlight = 500 watts/$m^2$
power of cell (10% efficient)
= 50 watts/$m^2$
area of solar cells required
$= \dfrac{1000 \text{ watts}}{50 \text{ watts/m}^2}$
= 20 $m^2$

**4** **a** solar cell—light energy
**b** coal-burning power station—chemical energy
**c** wind generator—kinetic energy
**d** hydro-electric power station—potential energy
**e** geothermal power station—heat energy

**5** **a** about $8.6 \times 10^9$ tonnes oil equivalent per day
**b** 2003
**c** You would need to extrapolate the graph to the year 2015. This prediction would be unreliable, however, because you do not know how steeply the curve will rise. It could even fall.

**6** The electricity we use at present comes from coal-burning power stations which release huge amounts of carbon dioxide into the atmosphere. The petrol we burn in our cars also produces carbon dioxide. So by cutting down our use of electricity and petrol we reduce our greenhouse gas emissions and consequently global warming.

**7** **a** 'Energy demand' is how much energy is required. 'Energy supply' is the energy produced from local or imported resources.
**b** The energy gap on the left is only small and was probably filled by importing oil, coal or natural gas.
**c** The surplus is where supply is greater than demand. During this stage the production of energy in Bananaland reached a maximum.
**d** The surplus will end about 2009.
**e** About 150 million tonnes of oil equivalent
**f** Import fuel, decrease demand, find more fossil fuel reserves, use nuclear energy, use alternative fuels (eg ethanol), use alternative sources (eg solar, wind, tides).

**8** There are a number of serious problems with the use of nuclear power, but it is a possible solution to our ever-decreasing reserves of fossil fuels and rising greenhouse gas emissions.

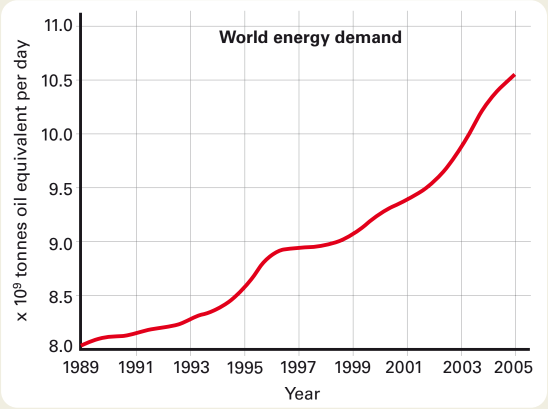
**9** Wind, geothermal and tidal energy can be used only in certain areas—where there are strong winds, volcanic action or hot rocks, or large tides.

**10** You could use a Remote Area Power Supply (RAPS) to generate electricity from solar cells and a wind generator (see page 149), if there was enough sunshine and wind. You could use a solar hot water system, and heating costs could be reduced by the house design described on page 147.



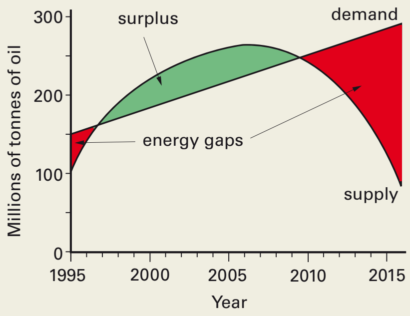
REVIEW

**5** The graph on the right shows world usage of energy from 1989 to 2005.
**a** How much energy was used per day during 1995?
**b** In which year did energy use first exceed $10 \times 10^9$ tonnes of oil equivalent per day?
**c** Why is it difficult to use this graph to predict our energy use in 2015?

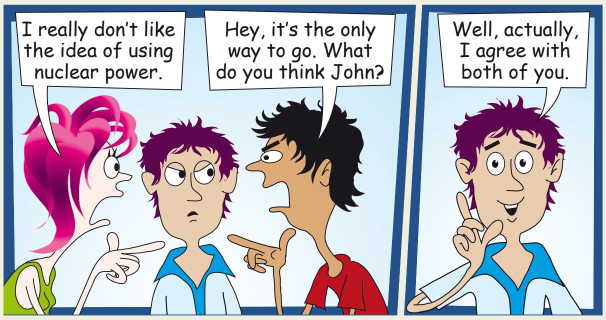



**6** The Australian government's greenhouse program suggests we try to cut down our use of energy. How would this reduce global warming?

**7** The graph below is a forecast of energy supply and demand for Bananaland.
**a** What is meant by 'energy demand'? What is 'energy supply'?
**b** Suggest how the energy gap on the left of the graph was filled.
**c** The middle of the graph shows an energy surplus. What is meant by this?
**d** When does the graph predict the surplus will end?
**e** How big is the energy gap predicted to be in 2015?
**f** Suggest at least three ways of filling Bananaland's future energy gap.




**8** A nuclear power company placed the cartoon advertisement below in a magazine. What is the advertisement trying to say? Do you agree with it?




**9** Why can energy sources such as wind power, geothermal and tidal power contribute only a small amount to our energy needs in the future?

**10** Imagine that you are an architect designing a holiday home. The home is to be built in the mountains where you cannot connect to the electricity grid. Describe how you would supply the home with electricity, hot water and heating.

Check your answers on pages 334–335.