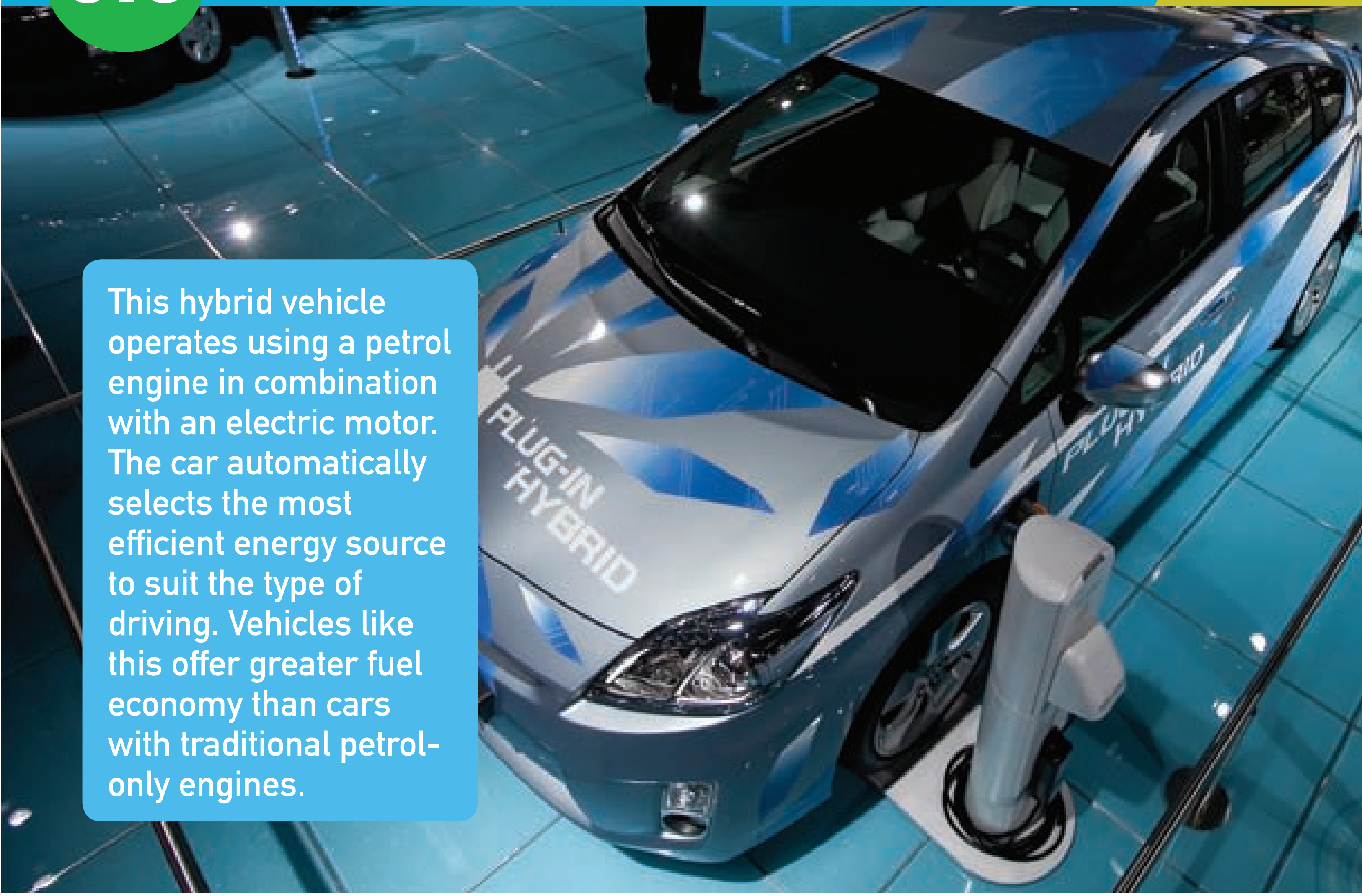
5.3 Energy-efficient design



This hybrid vehicle operates using a petrol engine in combination with an electric motor. The car automatically selects the most efficient energy source to suit the type of driving. Vehicles like this offer greater fuel economy than cars with traditional petrol-only engines.

Reducing energy consumption

Around the world, the demand for energy has never been greater than it is today. Most of the energy that we rely on to power our cars, heat and cool our homes and run electronic devices is produced from non-renewable sources such as coal, natural gas and oil. These non-renewable energy sources are limited in supply and burning them adds greenhouse gases to the atmosphere. More and more people are realising that these greenhouse gases increase the risk of globing warming and that may cause climate change.

In Australia, climate change is likely to:

- cause more frequent and intense droughts, storms and floods
- assist the spread of diseases, especially mosquito-borne diseases such as dengue fever and Ross River virus
- alter the populations of different species of plants and animals, especially those that live above the snowline in the southern states.

Reducing the amount of energy we use reduces the amount of greenhouse gases put into the atmosphere. We can reduce energy consumption in many ways, such as by switching off lights, computers and televisions when they are not in use. Walking, cycling or using public transport instead of relying on the family car will reduce your household's energy consumption. Replacing highly inefficient incandescent globes with more efficient compact fluorescent globes has already cut the energy bills of most households. Table 5.3.1 compares the efficiencies of incandescent and fluoroescent globes.

5.5
5.6

Table 5.3.1 Comparison of incandescent and compact fluorescent globes

Power	Approximate balloons of greenhouse gas produced over its lifespan	Purchase price	Expected operating hours	Approximate cost per year
75 watt incandescent 	3600	$1.00–1.20	1000–2000	$12.30
15 watt (75 watt equivalent) fluorescent 	730	$4.00–10.00 (cheaper if buying a pack of 2 or 3)	Around 8000 hours	$2.30

SciFile

Comparing labels

The energy rating label was first used in New South Wales and Victoria in 1986. Today, any household refrigerator, freezer, television, washing machine, clothes dryer, single-phase air conditioner or dishwasher sold in Australia must carry an approved energy rating label. It's the law!

SciFile

See the light!

Old-fashioned incandescent light globes converted most of their electricity into heat. The compact fluorescent globes available today use about 80% less electricity to produce the equivalent amount of light.

Energy rating labels

Household appliances vary in their energy efficiency. By purchasing appliances that are more efficient, your household will save energy and save on running costs. If you look around shops selling electrical appliances you will see that most large appliances carry a red and yellow **energy rating label**. A sample label is shown in Figure 5.3.1.

1 p198

Energy efficiency is shown by the number of stars on the label. The more stars (usually from 1 to 6) that are shaded on the energy rating label, the greater the energy efficiency of the appliance. You can determine which models are the most energy efficient by comparing the number of stars. The number found on the label provides the customer with an estimate of the amount of energy (usually listed in kilowatt hours per year) needed to operate the appliance for one year. The higher the number, the more energy is needed and the more the appliance will cost to run.

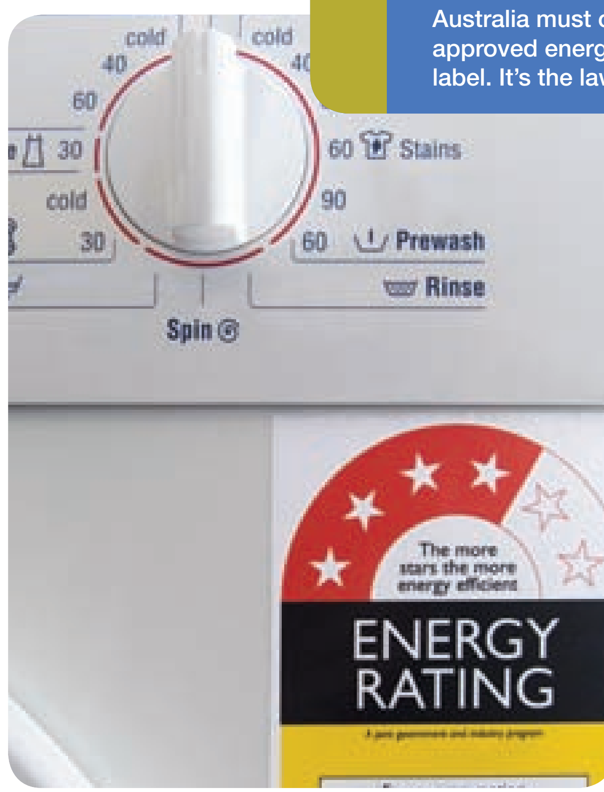


Figure 5.3.1 Appliances are tested under Australian standards to produce an energy rating label. Greater energy efficiency is indicated by more stars (or half stars) out of a possible six stars.

INQUIRY

science 4 fun

Shading a house

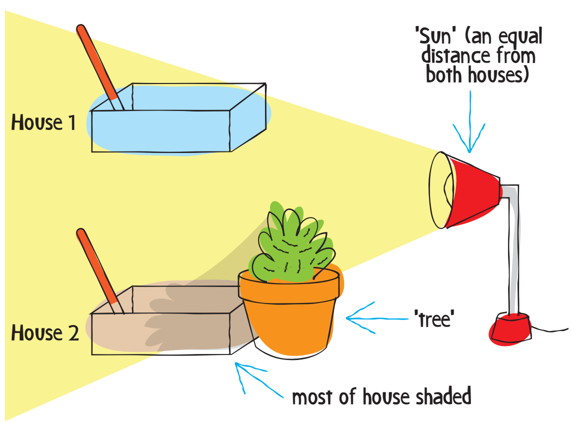
How much difference does shade make to the temperature inside a house?

Yes

Collect this …

- 2 identical shoeboxes
- incandescent desk lamp (sunlight will do on a warm day)
- pot plant or branch with leaves propped up in a pot with dirt
- 2 thermometers or temperature probes

Do this …



1. Position the two shoebox 'houses' an equal distance from the desk lamp (or outside in a sunny position).
2. Place the pot plant or branch close to one 'house' so that it is shaded as much as possible.
3. Measure the temperature inside each 'house' every 5 minutes for an hour.

Record this …

Describe what happened.

Explain why you think this happened.

SciFile

How much energy is that?

Energy rating labels display the typical amount of energy an appliance will use over one year. This value is stated in kilowatt hours. One kilowatt hour is equal to 3 600 000 joules of energy. This can also be written as 3.6 megajoules (MJ).

Efficient housing

Living in an energy-efficient house makes it easier for households to reduce their energy consumption. It is estimated that about half of the energy costs of running a house are to keep it warm in winter and cool in summer. Heat naturally flows from regions of higher temperature to regions of lower temperature. In winter, the warm air from a heater or heating system can flow through any cracks or gaps in the walls to the cool air outside or into the cooler garage. Alternatively, heat can rise up into the roof space. This means that a lot of energy is needed to keep a leaky house warm in winter. Similarly, in summer, the warm air outside will naturally flow into a cool house. To keep the house cool, air-conditioners might be used. However, they use a lot of energy, making them expensive to run. Adding **insulation** to ceilings and between the walls of a home reduces the heat flowing outside in winter and inside in summer. This makes heating and cooling more effective and makes a house more comfortable.

5.7

Figure 5.3.2 This zero emissions house has been constructed in a Victorian housing estate. Over the course of a year, solar panels on the roof generate as much energy as the house will use.

The **National House Energy Rating Scheme** uses computer simulations to provide a star rating for the built exterior shell of a house. A rating of zero stars means that the house is poorly designed and does little to protect its occupants from heat in summer and cold in winter. A house rated at 10 stars probably won't need any heating or cooling because it remains at a comfortable temperature all year round.

Improvements in house design can be achieved by:

- considering the orientation of windows—in Australia this usually means placing large windows along the northern and eastern sides of the house, with small or no windows on the hot western side and the cooler southern side
- considering the orientation of the house on the block of land—in Australia, this usually means having living areas facing north and other rooms (such as the bathroom) facing south
- tinting or shading west-facing windows
- including coverings such as eaves, verandas or pergolas over the north- and west-facing windows
- insulating the floor, walls and roof to reduce energy losses.

Building regulations throughout Australia require new homes to be built to specific minimum energy standards. Figure 5.3.3 shows design features that make a house more energy efficient.

Innovative design

The need to save energy has led to new and innovative designs to increase efficiency. Some of these ideas include regenerative braking, interior cooling in parked cars, magnetic refrigeration, LED lighting, organic photovoltaics and dry washing mashines.

The **regenerative braking** system of a hybrid car captures some of the vehicle's kinetic energy as the car slows down. Stored in a battery, this energy is then used to power the car's electric motor when needed. Elevator (lift) manufacturers are investigating how to use this idea to save the energy used by lifts.

Some luxury cars now incorporate solar cells on the roof of the car. These cells power interior fans that prevent the inside of the car from getting too hot when the car is parked. This reduces the need for air conditioning when the car is being driven.

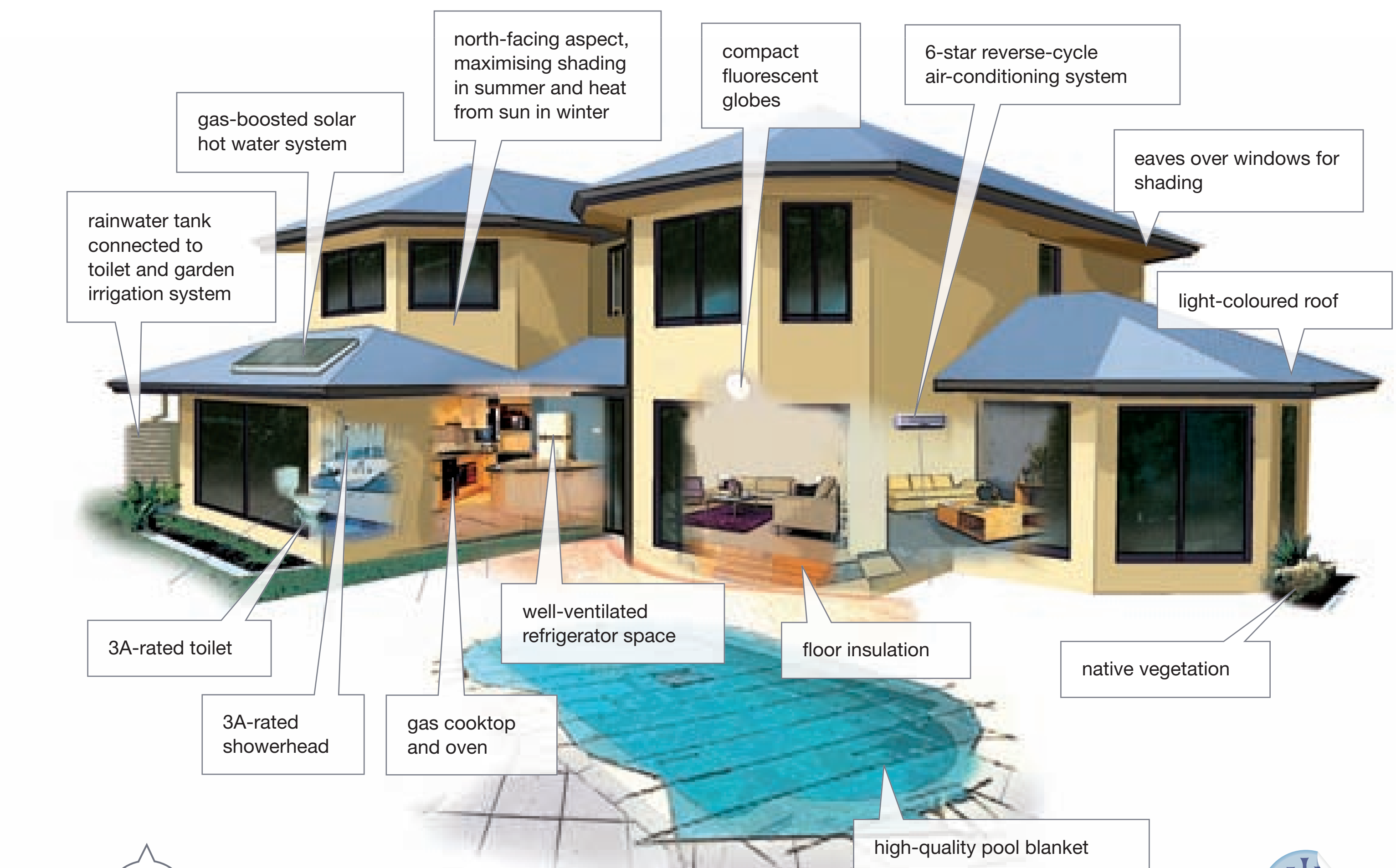


Figure 5.3.3 The design features of this home allow its occupants to be comfortable while reducing energy consumption. They also include water-saving features.

2 p199

Magnetic refrigeration is a new way of providing cooling using a magnetic field. Once fully developed, this technology could reduce the energy used by refrigerators and air conditioners.

LED (light-emitting diodes) are very bright but use very little energy. Current LEDs produce a cool bluish light, but manufacturers are working on producing LEDs with a warmer colouring so they can be more widely used. Figure 5.3.4 shows the spectacular use of coloured LEDs to light buildings.

Organic photovoltaics are a new generation of flexible and cheap solar cells that are made from carbon-based materials. Researchers are currently trying to increase the efficiency of these solar cells from their current 5% to 15–20% efficiency of a traditional photovoltaic cell. If their efficiency can be improved, these cells have huge potential for widespread use. An organic photovoltaic cell is shown in Figure 5.3.5.

Dry washing machines are currently being developed. These machines clean clothes using thousands of dirt-absorbing nylon beads and use 90% less water than a conventional washing machine. As the dry washing machine only uses a small amount of water, much less energy is required to pump water in or out than in a normal washing machine. Energy is also saved because the water does not need to be heated. Finally, because the clothes that come out are already dry, people who rely on clothes dryers will not need to use them!

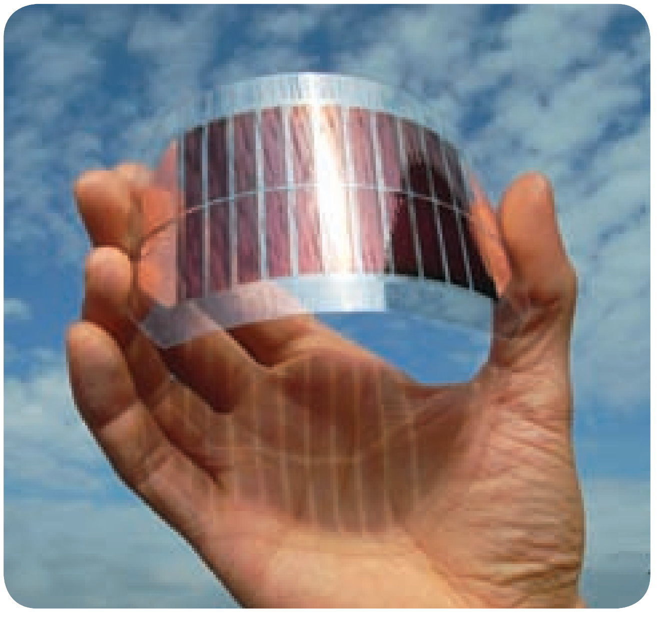


Figure 5.3.5 Lightweight, flexible and cheap organic solar cells could be attached to bus stops, buildings and even clothing to generate electricity.

Figure 5.3.4 Over 20 000 LEDs were installed on Council House in the city of Perth. This energy-efficient lighting display is controlled by computer.

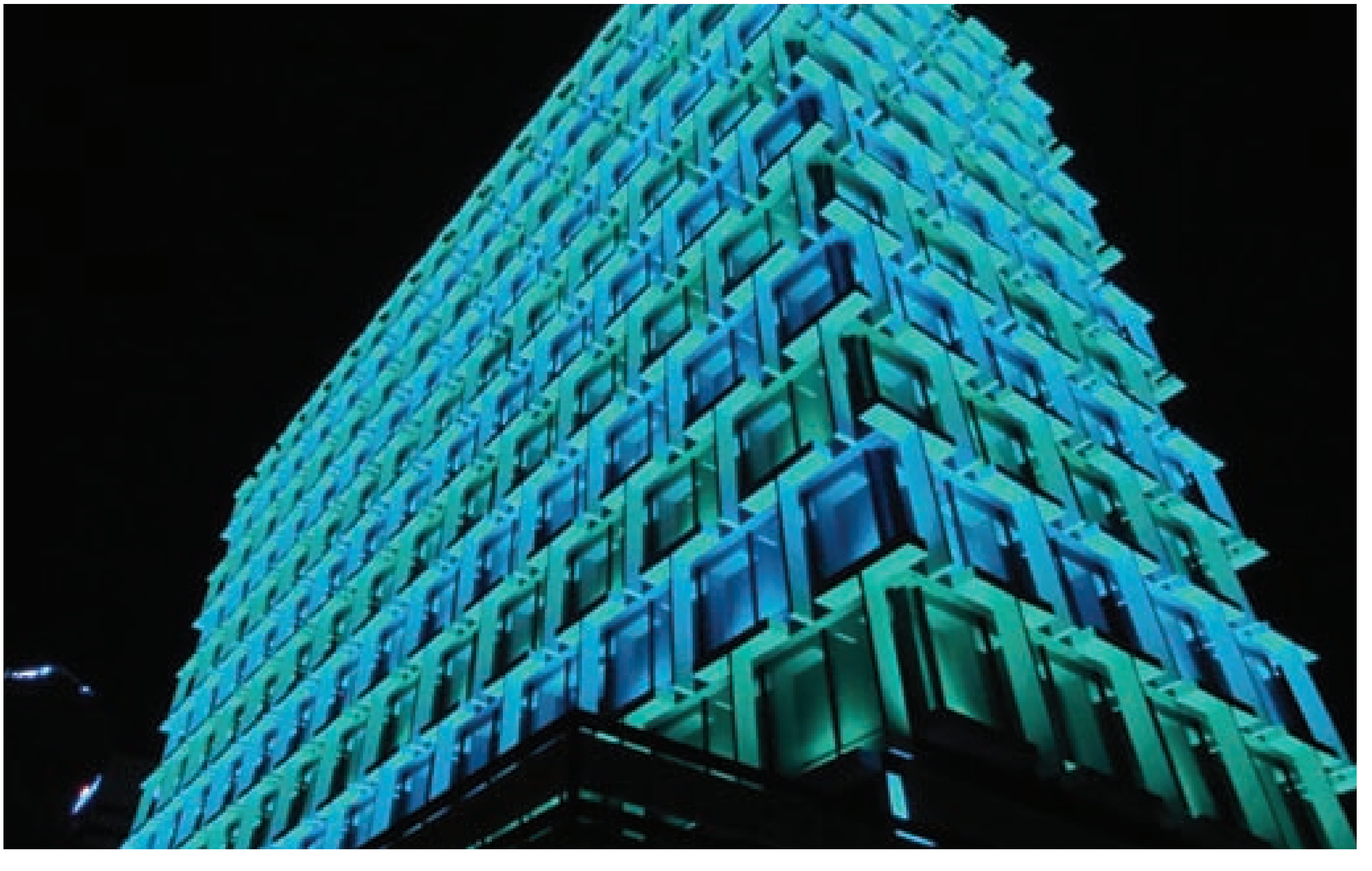


Figure 5.3.6 Otto Lilienthal died in 1896 after losing control of a glider like this one in a strong wind.

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

The development of aircraft

Humans have wanted to fly for thousands of years. Some of the important developments that have led to modern aircraft are outlined below.

400 BCE

Kites were flown in China.

1480 CE

Leonardo da Vinci drew diagrams of a machine with wings—an 'ornithopter'—that he thought could help people fly.

1799

British scientist Sir George Cayley (1773–1857) discovered many of the principles of flight. He did this by experimenting with the shape of the wings on a glider that would allow smooth air flow. In 1799 he designed a fixed-wing flying machine with airfoil-shaped wings for lift (the same shape as modern wings), a moveable tail for control and 'flappers' to provide thrust.

1891–1896

German engineer Otto Lilienthal (1848–1896) made over 2500 flights in monoplane and biplane gliders he designed. His gliders, such as the one shown in Figure 5.3.7, were the first to travel a long distance.

1903

American brothers Orville and Wilbur Wright researched the work of earlier aviation pioneers and tested theories of air flow using kites and balloons. The Wright brothers tested different shapes of aircraft wings in a wind tunnel to assist them in designing their gliders. They later added a gas-powered engine. In 1903, in North Carolina, USA, Orville Wright flew 36.5 metres in the *Flyer*—the first powered, heavier-than-air controlled flight (see Figure 5.3.7). By 1905 they had achieved a flight of 39.4 kilometres.

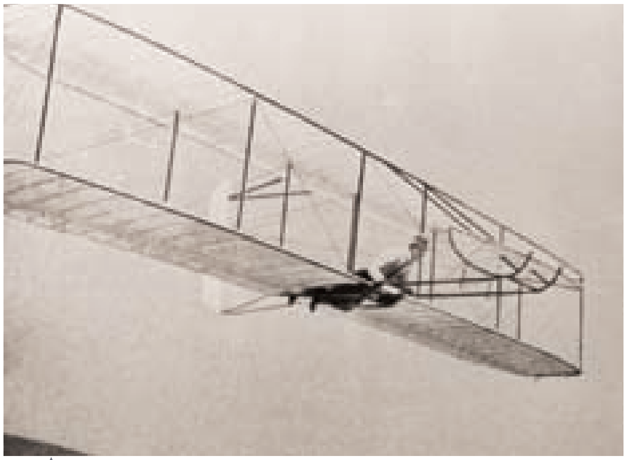


Figure 5.3.7 Orville Wright lying on the lower wing of the *Flyer*

continues on page 196

continued from page 195

ENDEAVOUR

early 1900s

The first few decades of the 1900s were times of great development in aviation. To build faster and more efficient aircraft, the bodies of the aircraft needed to be enclosed to reduce the drag on them when in flight. Aircraft were then made from stronger (but not heavier) materials like aluminium. Figure 5.3.8 shows US aviator Charles Lindbergh, who made the first flight across the Atlantic Ocean in 1927, from New York to Paris. Australian aviator Charles Kingsford Smith made the first flight across the Pacific Ocean between the USA and Australia in 1928.

Figure 5.3.8 Charles Lindbergh (1902–1974) flew his aircraft *Spirit of St Louis* from New York to Paris in the first solo flight across the Atlantic Ocean.

1950s

Aviation boomed following World War 2. Most aircraft were built with piston engines and propellers to provide thrust for flight.

Passenger jets such as the Boeing 707 were manufactured from the 1950s.

Figure 5.3.10 The use of composite materials such as carbon–fibre reinforced plastic in the structure of this modern aircraft increases fuel efficiency and reduces greenhouse emissions.

1937

British pilot Frank Whittle designed the first turbo jet engine, which was used to power an aircraft in 1941. The jet engine shown in Figure 5.3.9 enabled aircraft to travel at high speeds.

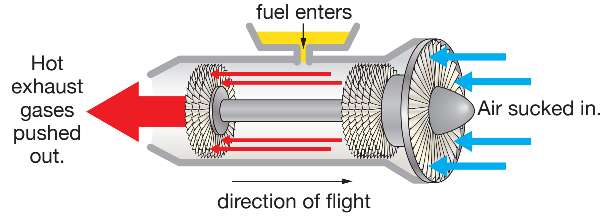


Figure 5.3.9 A jet engine uses a spinning fan to draw in outside air, which is compressed by a second fan. Fuel is mixed with this compressed air, which burns, expelling hot exhaust gases at high speed. The force produced by releasing the exhaust gases propels the aircraft forward.

Now

The engines of passenger jets such as the A380 airbus shown in Figure 5.3.10 have become more efficient and the materials used to construct the aircraft are lighter.

Improvements in aircraft design are ongoing. Figure 5.3.11 shows the design of a solar plane called *Solar Impulse* that successfully completed a 26-hour flight in 2010. Its 61-metre wingspan holds the 12 000 solar cells that power its flight. The aircraft carried only one passenger—the pilot. The flight is encouraging for future development of solar technology.

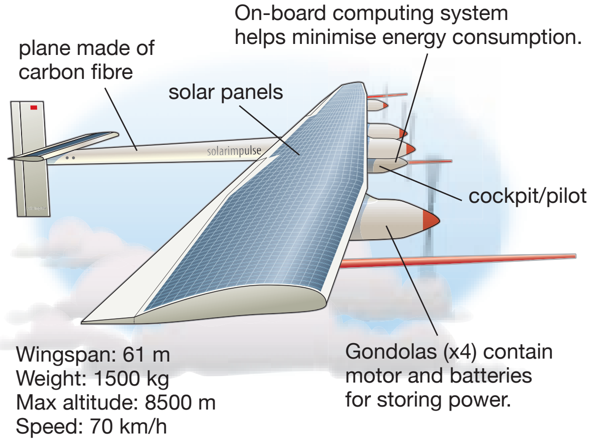


Figure 5.3.11 *Solar Impulse* is made from lightweight carbon fibre and utilises super-efficient solar cells, batteries and four engines to fly.

5.8

5.3 Unit review

Remembering

1 **List** four ways you can save energy.

2 **List** the types of appliances that must carry an energy rating label in Australia.

3 **Recall** the direction of heat flow by selecting the correct words to complete the following statement.

Heat flows from regions of lower/higher temperature to regions of lower/higher temperature.

4 **State** the aviation record that the Wright brothers achieved in 1903.

Understanding

5 **Explain** why incandescent light globes have now almost completely been replaced by compact florescent globes.

6 **Explain** what the star rating in Figure 5.3.1 on page 191 tells a consumer about the energy efficiency of this appliance.

7 **Describe** three ways in which the house shown in Figure 5.3.4 on page 193 reduces household energy consumption.

8 **Explain** how adding insulation to a house and sealing up gaps can reduce the energy costs of heating and cooling the house.

9 **Explain** how regenerative braking makes a car more energy efficient.

10 It is important for developers to improve the efficiency of organic photovoltaics to ensure their use in the future. **Explain** why.

11 **Explain** how a dry washing machine could save energy compared to a regular washing machine.

Applying

12 You touch a cool glass of soft drink on a warm day. **Identify** whether heat flows from your hand into the glass or from the glass into your hand.

Analysing

13 **Analyse** why the bodies of aircraft needed to become enclosed in order to improve their efficiency in the air.

Evaluating

14 The energy rating label system was revised for use in Australia in the year 2000. At that time, the most energy-efficient appliances on the market only had a rating of 3 or 4 out of a possible 6 stars. **Propose** why the designers of the system set it up in this way.

15 **Predict** what a car would be like if it was 100% efficient.

Creating

16 **Construct** a scale timeline outlining the important years of aviation history as described on pages 195 and 196.

17 **Design** an advertisement for a new energy-efficient appliance. **Outline** how your appliance will save energy and why people should buy it.

Inquiring

1 Investigate how the shape of the wing of a paper plane affects how far the plane will travel. Using sheets of A4 paper, test the effect of three different designs. Summarise your findings and include diagrams of the three designs you tested.

2 The typical energy consumption of new refrigerators and freezers decreased by 40% in the years 1993 to 2006.

- a Find information about the energy labelling system currently used in Australia.
- b Using a suitable Australian website, compare the energy use of three different brands of washing machines, toasters and clothes dryers. Rank the appliances from most to least energy efficient.

3 Research the work of Sir George Cayley or Otto Lilienthal and outline the contribution they made to aviation.

4 In the World Solar Challenge, teams build and race solar-powered vehicles some 3000 km from Darwin to Adelaide. Research and write a newspaper report or interview about the winning team from the most recent World Solar Challenge.

5.3 Practical activities

1 Building a kettle

Purpose

To build a model kettle and study its energy transformations.

Materials

- 40 cm nichrome wire
- pencil
- 150 mL beaker
- connecting wires
- power supply
- thermometer (or data-logging temperature probe)
- bench mat

SAFETY

Do not touch the nichrome wire while it is hot as it can give a nasty burn. Let it cool completely on a bench mat before packing it away.

Procedure

1 Make a heating element as shown in Figure 5.3.12 by winding the middle section of the nichrome wire around a pencil. Leave 10 cm of straight wire at each end as connecting leads. Remove the pencil.

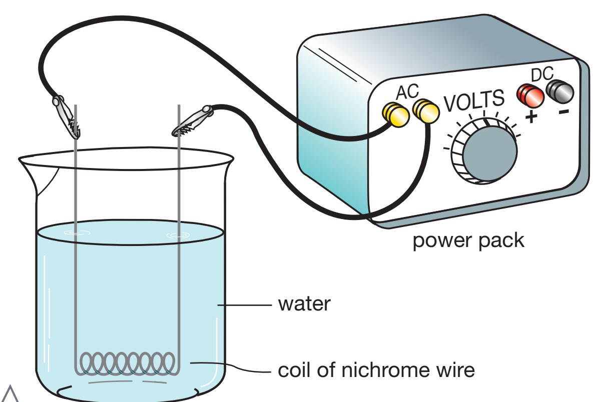


Figure 5.3.12

2 Add about 70 mL of water to the beaker.

3 Place the heating element in the beaker, making sure it is completely covered by water.

4 Connect the element to the power supply using the connecting wires.

5 Set the power pack to 4 volts and switch the power supply on.

6 Record the temperature of the water every minute for 10 minutes in a table like the one below.

Results

1 Copy the results table into your workbook and record the temperatures.

Time (min)	Temperature (°C)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

2 Construct a line graph showing the temperature of the water in the beaker over the 10 minutes.

Discussion

1 **Use** your graph to **predict** how long it would take for the water to boil.

2 **State** the energy source for your kettle.

3 **Name** the form of energy it was converted into.

4 **Identify** three household appliances that rely on the same energy transformation as this kettle.

5 If this kettle was graded for an energy rating label, it would probably have a rating of zero or 1 star.

a **Explain** why the kettle would not have a high star rating.

b **Propose** two ways of changing its design to make it more energy efficient.

2 Effect of double-glazing on heat loss

Purpose

To investigate the effect of double-glazing in preventing heat loss.

Materials

- 2 × 100 mL beakers
- cling wrap
- 4 cardboard discs of the same size, slightly larger in diameter than a 250 mL beaker
- stopwatch
- 2 thermometers (or data-logging temperature probes)
- hot water

SAFETY!
Be careful when handling hot liquids.

Procedure

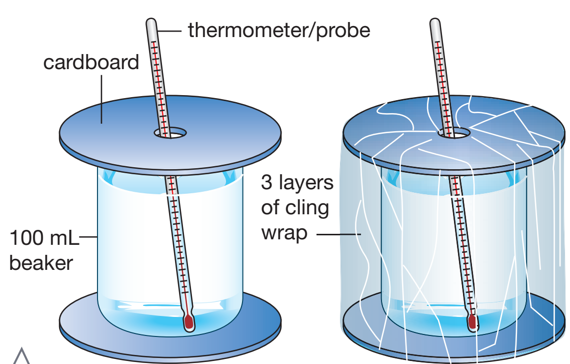


Figure 5.3.13

1. Copy the results table into your workbook.
2. Wrap one beaker with three layers of cling wrap.
3. Position each beaker on a cardboard disc. Punch identical holes in the centre of the two remaining discs to fit a thermometer or probe as shown in Figure 5.3.13.
4. Carefully add 80 mL of hot water to each beaker. (Ensure water is the same temperature in each.)
5. Place cardboard discs on top of each beaker and insert the thermometers or temperature probes.
6. Record the temperature in each beaker every minute for 10 minutes.

Results

Copy the results table into your workbook and record the temperatures.

Time (min)	Water temperature in beaker without cling wrap (°C)	Water temperature in beaker with cling wrap (°C)
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Discussion

1. **State** whether the layers of cling wrap had an effect on the heat loss from the beaker.
2. **Explain** how double-glazing windows can reduce energy losses from a house.
3. **Propose** how the design of this experiment could be improved.