# ENERGY 3

3.1 Energy can be transferred

3.2 Potential energy is stored energy

3.3 Moving objects have kinetic energy

3.4 Energy can be transformed

3.5 Energy cannot be created or destroyed

3.6 Energy efficiency can reduce energy consumption

3.7 Solar cells transform the Sun's light energy into electrical energy

3.8 Engineers use their understanding of energy to solve problems

## What if?

### Rolling cars

**What you need:**

ramp, permanent marker, large toy car, tape measure, weights, Blu Tack

**What to do:**

1. Set the ramp up on the floor so it is at an angle.
2. Draw a starting line at the top of the ramp.
3. Place the large toy car on the starting line. Release the car.
4. Measure how far the car rolls from the bottom of the ramp.

**What if?**

» What if weight were added to the car? Would it roll further?

» What if the ramp were placed at a different angle?

» What if the ramp were longer?

# 3.1 Energy can be transferred

All objects have energy. Energy is the ability to do work. It is how things change and move. It cannot be created or destroyed. Moving objects, stretched objects and objects high off the ground all have energy. When energy is passed from one object to another, it is said to be **transferred**.

**Figure 3.1** We use energy to walk and carry things.

## Where does energy come from?

We have all felt the energy of the Sun on a hot day. It can warm our skin and even cause sunburn. Plants are very efficient at absorbing the energy of the Sun. The energy is transferred from the Sun to the plant. This can be shown using a flow diagram (see Figure 3.2) where an arrow shows the direction of energy flow.

The plant uses the energy to grow. Eventually animals (including us) eat the plants and the energy is transferred again (see Figure 3.3).

We use the energy for moving, including walking. This also produces heat that then warms up the air around us (see Figure 3.4).

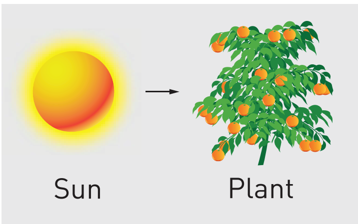


**Figure 3.2**

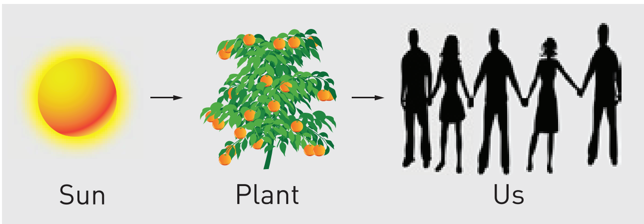


**Figure 3.3**

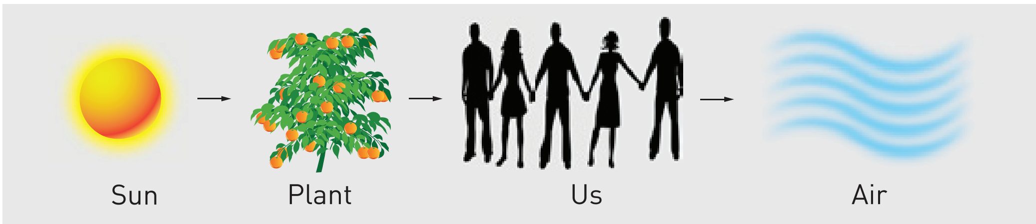


**Figure 3.4**

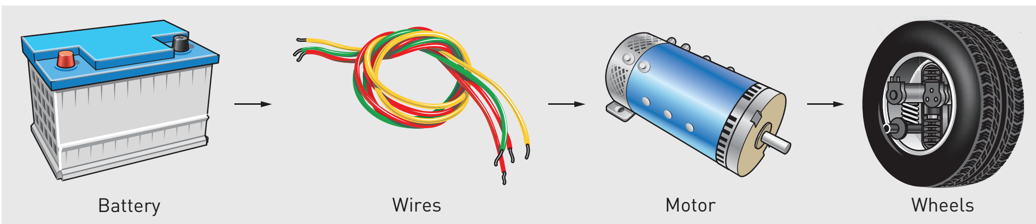


**Figure 3.5**

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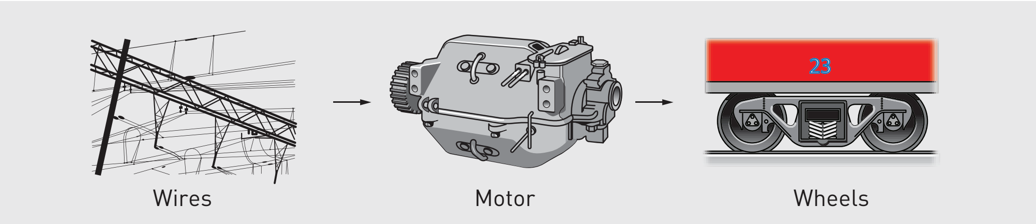


**Figure 3.6**

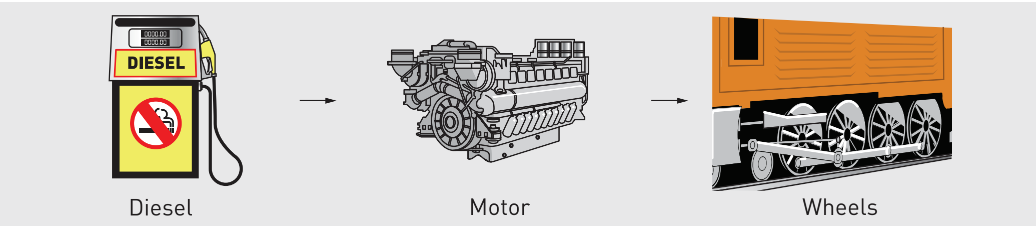


**Figure 3.7**

## Where does energy go?

Electric cars are being designed to use the energy stored in batteries, rather than petrol, to power an electric motor that makes the wheels turn. This can be shown using a flow diagram (see Figure 3.5).

Public transport uses energy too. Trams and metropolitan trains transfer the electrical energy from the overhead wires into the motor that makes the wheels move (see Figure 3.6).

Trains that travel to country areas or interstate usually run on diesel fuel and don't need overhead electrical wires. The engines in these trains burn diesel fuel, transferring the energy into wheel movement via the motors (see Figure 3.7). Ships and planes use a similar process in their engines.

**Figure 3.9** Powerlines provide electrical energy for public transport.

**Figure 3.8** Hybrid cars use both a petrol engine and an electric motor to send power to the wheels.

**Figure 3.10** Aircraft use higher quality fuels than road transport vehicles to minimise weight and waste.

Figure 3.11 Powerlines aren't practical in rural areas, so diesel fuel is used.

Figure 3.12 Earphones transfer energy in batteries to our ears as sound.

Figure 3.13 The internal components of a mobile device.

## Energy transfers for entertainment

Both CD and DVD players need to transfer energy from the batteries to wires. The energy is then transferred to a laser light, enabling it to read the information stored on the CD or DVD. Tiny microscopic pits on the disc make up the digital code – a bit like a miniature version of Braille used by the visually impaired. The laser, which is a very pure type of light, reads the code, transferring its energy to the speakers and the screen.

A mobile phone also uses a speaker to produce the sound of a person's voice or the various ring tones and beeps that the phone makes. Home phones use a speaker too, as do televisions, CD systems, radios and many other devices. They all transfer energy from the battery to the wires, then to the speaker to make sound.

A television **remote control** transfers energy from the device through the air as light, and into the television set (see Figure 3.14). In fact, most remote controls use infrared light, which is the invisible type of light usually associated with heat. The remote control sends a pulse of infrared light that represents a particular command, such as to change the channel or increase the volume. An infrared light detector on the television receives the light signal and transfers it back into electrical energy, which then carries out the command.

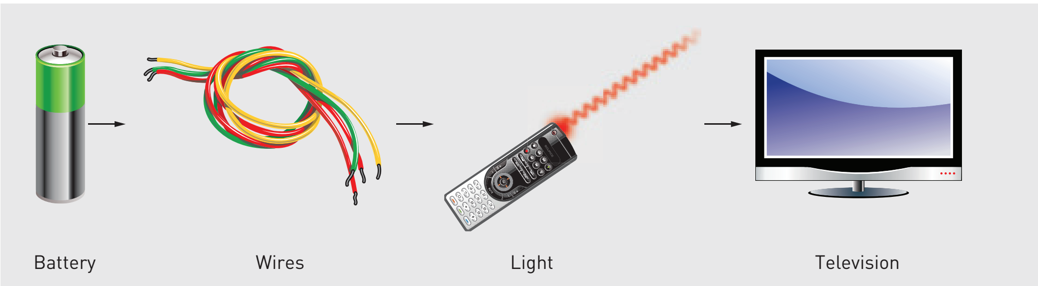


Figure 3.14

**Figure 3.15** A television remote control uses an infrared light-emitting diode (LED) to operate the television.

## Check your learning 3.1

### Remember and understand

1 What is energy?

2 What type of devices could the following flow diagrams represent?

- a wires → motor → air
- b battery → wires → light globe
- c sun → muscles → bicycle

3 Make a summary of the entertainment devices mentioned in this section and draw flow diagrams for the energy transformations they perform.

4 Why is the direction the arrows point in a flow diagram important?

5 Copy Figure 3.16 and label each stage in the flow diagram.

### Apply and analyse

6 Why do country trains mostly use diesel instead of electrical wires?

7 How important is energy for transport?

8 What is the ultimate source of all energy?

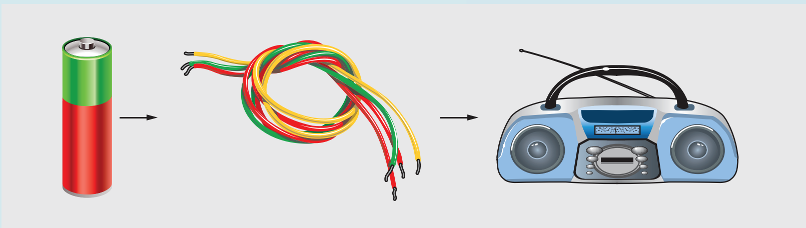

**Figure 3.16**

# 3.2 Potential energy is stored energy

**Potential energy** is energy that is stored in objects and is waiting to be used. This stored energy can be the result of a change of shape (stretching or squashing) or an object's height above the ground. This energy can be stored in many forms. Gravitational potential energy is the energy stored in an object that is high above the ground. Elastic potential energy is the energy stored in an object that has changed in shape. Chemical potential energy is the energy that is stored in any chemical. Nuclear potential energy is the energy stored in the centre of an atom.

Figure 3.17 Power riser jumping stilts rely on elastic potential energy.

## Elastic potential energy

A trampoline has the ability to 'store' energy, or hold it, for later use or if things change. The springs and the mat of the trampoline stretch under our weight and hold this stored energy. The more they stretch, the more energy they hold. The energy is returned to our bodies when the springs and mat return to normal and throw us into the air. Energy that is stored through stretching or squashing is called **elastic potential energy**.

## Gravitational potential energy

If we lift an object up to a height, it gains **gravitational potential energy** (abbreviated to just 'GPE').

The larger the mass and the larger the height, the more GPE the object gains. Have you ever noticed that falling a greater distance produces a greater 'thud' and can hurt more? This is because of the amount of GPE. As an object falls down, the object's GPE can be

Figure 3.18 Pogo sticks release the elastic energy of springs to provide motion.

Figure 3.19 This television has GPE when raised above the ground.

EXPERIMENT 3.2: WHAT IF THE AMOUNT OF ELASTIC POTENTIAL ENERGY WERE INCREASED?
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transformed into other forms of energy. This happens when a person plays on a slide at the playground. The higher they climb, the more GPE they get. When they slide down, the GPE decreases. The person gains movement energy. They may also feel the friction of the slide as heat or even as a zap of static electrical energy.

## Chemical potential energy

After we have done a lot of exercise, we often crave foods that we believe will restore our energy levels. These foods, usually sweet things, release stored chemical energy really quickly to satisfy our cravings. All foods have some energy stored in them, but the difference is how quickly the energy can be released.


**Figure 3.20** Energy drinks contain chemical potential energy.

Fuels, such as natural gas and petrol, provide us with energy too. A Bunsen burner uses the burning of natural gas to provide heat for laboratory experiments. Petrol has chemical energy stored in it, as do explosives and batteries.

These devices all contain chemical potential energy that can be released when we need it. Some batteries can be recharged – the **chemical potential energy** (CPE) can be replaced.

## Nuclear energy

Although nuclear energy is used throughout the world, it is not used in Australia. **Nuclear energy** involves the reaction at the centre of atoms. When atoms react in chemical reactions, they usually release only small amounts of energy. However, if the centres or nuclei of those atoms can be made to react, the amount of energy released is much, much larger. In fact, the amount of energy released is so huge that it can cause massive amounts of destruction.

**Figure 3.21** The energy released from a nuclear explosion is much, much greater than that from other types of explosions.

### Check your learning 3.2

#### Remember and understand

1. List four examples of devices or situations that involve potential energy.
2. What type of energy is stored in a battery?
3. We get our energy from the chemicals in food. What type of energy is this?
4. Biofuel is an alternative source of energy that comes from burning the energy stored in plants. What type of potential energy is biofuel?
5. Describe four devices, other than those mentioned already, that possess elastic energy.

#### Apply and analyse

6. Describe how a person might use a bow to shoot an arrow. What type of potential energy is used in this process?
7. Name three countries that use nuclear power to generate electrical energy.

**Figure 3.22** Plastic slides are great at zapping us with static electricity, although it depends on the weather and the clothes we wear.

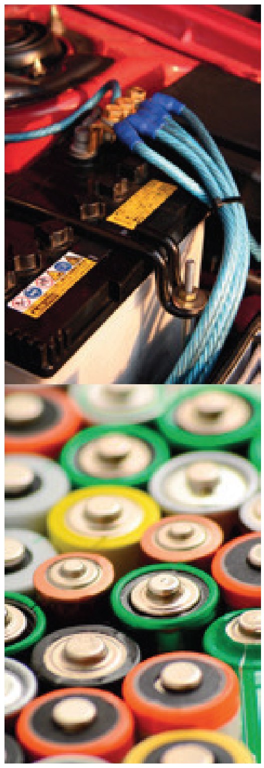

**Figure 3.23** The CPE in batteries can be transformed into electrical energy to power almost anything.

# 3.3 Moving objects have kinetic energy

The energy of movement is more scientifically called **kinetic energy** (KE). Whenever objects or people move, they are using kinetic energy. The most common way we think of kinetic energy is when we see a moving object. It takes energy to force an object such as a car to start moving. Once it is moving, the energy has passed to the car. It is this energy that is called kinetic energy. The faster the object is moving, or the more mass the object has, the greater the kinetic energy. Even objects too small to be seen can have kinetic energy.

**Figure 3.24** Kerosene lamps were used for many years before the invention of electricity.

## Light energy

Light energy is essential to our lives and people have invented lots of devices to help us see in the dark. The humble electric light bulb revolutionised the world. Oil and gas lamps were popular in the old days and a torch helps us see at night when we go camping. But the best source of light is, of course, our Sun.

Light energy is one type of energy that our eyes can usually detect. We see a range of colours (red, orange, yellow, green, blue and violet) in the visible spectrum, but the light we see is part of a larger group that is called electromagnetic radiation. This large group includes ultraviolet light, microwaves and x-rays. The study of light energy is known as optics.

The main reason life exists on Earth and not on other planets is because our atmosphere allows the right amounts of the different forms of light energy coming from the Sun to reach the surface. Plants rely on the light and heat from the Sun to make their own food and, of course, to provide food for animals.

**Figure 3.25** Sunlight is essential for all life on Earth. Without it, it is doubtful whether life would exist.

CHALLENGE 3.3: EXPLORING SOUND ENERGY
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**Figure 3.26** Solar-powered speed signs are becoming common all across our country and help save energy too.

We are now trying to capture the light energy as efficiently as plants do. The relatively recent invention of **solar cells** to turn light from the Sun directly into electricity is now used to power many devices, such as calculators, street lights and even cars.

## Heat energy

Heat energy is more scientifically known as **thermal energy**. Thermal energy can be generated by friction, such as by rubbing your hands together or by the rubbing of the tyres on the road. It is also commonly generated by burning chemicals or by electrical devices. We experience heat energy being transferred from a high temperature place to a lower temperature place as we heat up or cool down. For example, an ice block feels cool because it takes the thermal energy away from our hands.


**Figure 3.27** The heat of a 'burn-out' creates great clouds of smoke.

## Electrical energy

All substances are made up of positive and negative electric charges that, when separated, have **electrical energy.** This means that they are in a state of excitement and are trying to get back together again. If the positive and negative charges are locked together in one area, such as a wire, the separated charges can easily move back together. As they try to connect, the electrical energy they had when separated gets changed into the light, heat or movement we are used to seeing from electrical lights, heaters or motors.

## Sound energy

Have you been at a very loud concert and stood near the huge speakers? If so, you will remember that you not only heard the deep bass sound, but also felt it in your body. You can feel the same vibrations in the car if you put your hand on the dashboard when the sound system is on full blast. Sound is made when things vibrate. Every time you make a sound – whether it be playing a musical instrument or speaking or singing or even whispering – you are making vibrations. Vibrations are simply tiny movements back and forth. Vibrations can occur in gases, liquids and solid things such as speakers – even the desk in front of you. Energy is needed to make sound. For example, unless a drummer uses energy to hit the drums, the drum skin will not start to vibrate and will not make a sound. So, do you think **sound energy** is a type of kinetic energy?

### Check your learning 3.3

#### Remember and understand

1. What is the scientific term for 'movement energy'?
2. What is moving in electrical energy?
3. What is moving when a guitar produces sound energy?
4. What is another name for heat energy?
5. What are solar cells used for?
6. What features of a car would absorb the driver's kinetic energy in a collision?

# 3.4 Energy can be transformed

When energy is changed from one type of energy to another, we say it has been **transformed**. For example, when the energy in a battery is transferred to the wires in a circuit, the energy is transformed from chemical potential energy into electrical energy. Water at the top of a waterfall has gravitational potential energy. This is transformed into kinetic energy as the water moves down to the bottom of the waterfall. Before investigating energy transformations, there are a few things you need to know.

## Flow diagrams

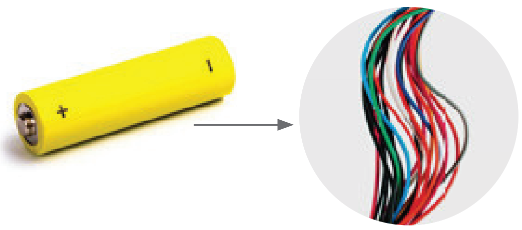
How do we represent an energy transformation scientifically? Flow diagrams that use an arrow to represent the transformation process help with this idea.

1 The arrow points in the direction of the transformation.

2 The energy input is written at the back of the arrow.

3 The useful energy output is written at the tip of the arrow.

For example, the battery in a mobile phone transforms chemical energy into electrical energy. The previous sentence describes this energy transformation, but using a flow diagram it would be:




Sometimes there is more than one energy output, so we try to concentrate on the main one. Minor energy outputs are known as by-products. Think how you would write the energy transformation in a light bulb. What is the energy input? What is the main energy output? Is there a by-product (wasted energy)?

In some devices there are several energy transformations that make up an energy story, resulting in an energy chain. For example, the energy story in a mobile device would be described in the following way:

The chemical energy stored in the battery is transformed into electrical energy. The electrical energy flows through the wires to the headphones, where it is transformed into kinetic energy as the tiny speakers in the headphones vibrate. This is then transformed into sound energy, which our ears pick up.

As a flow diagram, this energy chain would be:


**Figure 3.28** Chemical energy in the mobile device battery is transformed into the sound energy that we hear.

**CHALLENGE 3.4:** ENERGY CONVERTERS
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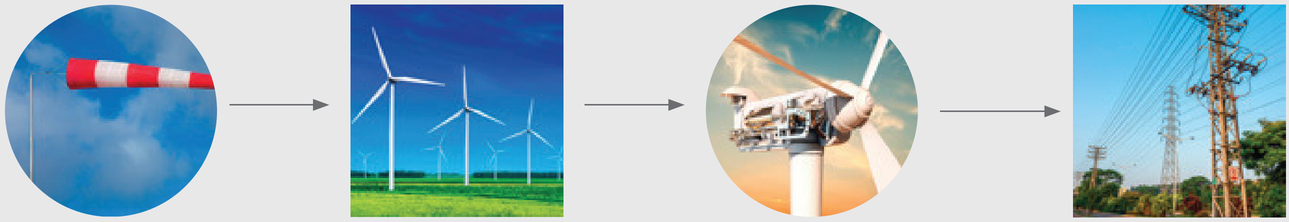



**Figure 3.29**

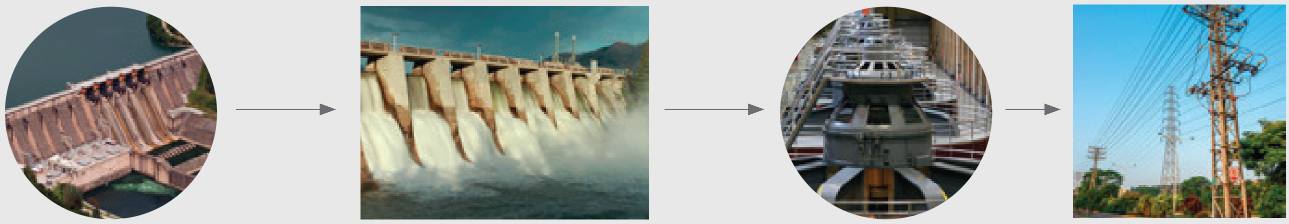



**Figure 3.30**

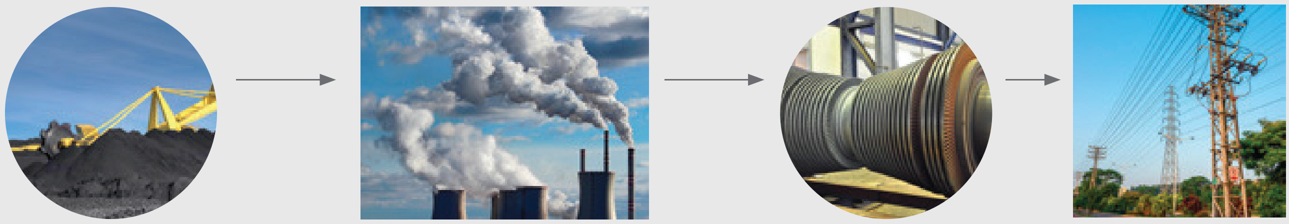



**Figure 3.31**

## Generating electricity

There are many ways of generating electricity. Wind generators use the wind to turn a turbine. The kinetic energy of the wind is transferred to the kinetic energy of the turbines. The turbines then transform this energy into electrical energy (see Figure 3.29).

Hydroelectricity plants have large dams that store water. The large amount of water is usually part of the way up a hill. Therefore the water has gravitational potential energy. Pipes control the flow of water down through the turbine, transforming the gravitational potential energy into kinetic energy of the turbine (see Figure 3.30).

Coal based electricity generators use the coal to heat water. The resulting steam rises, forcing the turbines to turn and transforming the kinetic energy into electrical energy (see Figure 3.31).

You use the electrical energy that comes from these generating plants for many different things: charging your mobile phone, cooking dinner, turning on a light. Energy may take many shapes or forms before you can use it.

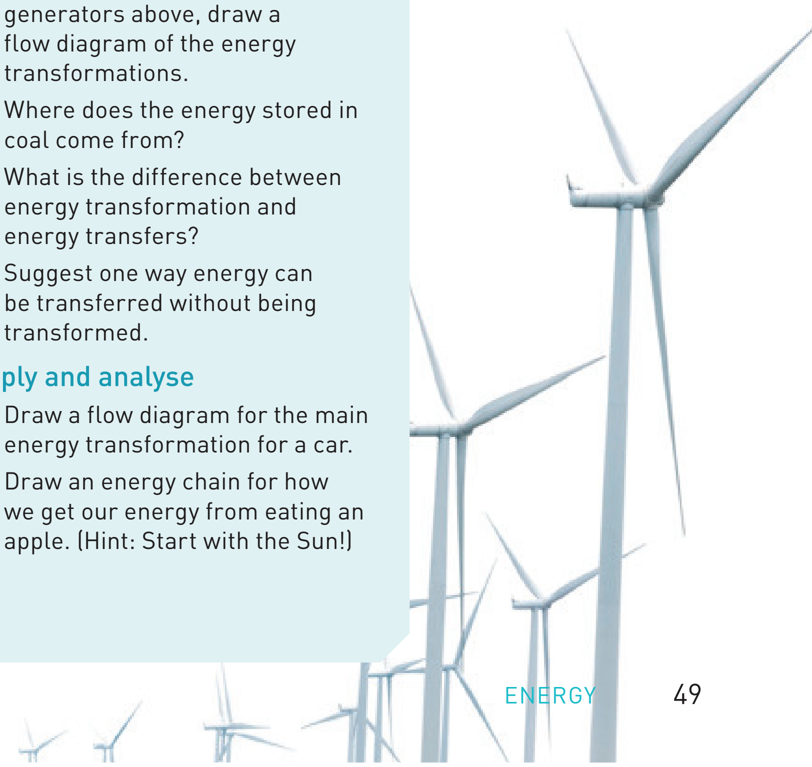
## Check your learning 3.4

### Remember and understand

1. For each of the electricity generators above, draw a flow diagram of the energy transformations.
2. Where does the energy stored in coal come from?
3. What is the difference between energy transformation and energy transfers?
4. Suggest one way energy can be transferred without being transformed.

### Apply and analyse

5. Draw a flow diagram for the main energy transformation for a car.
6. Draw an energy chain for how we get our energy from eating an apple. (Hint: Start with the Sun!)



# 3.5 Energy cannot be created or destroyed

Energy cannot be created or destroyed. This is called the **law of conservation of energy** and can be seen in any energy transformation. Sound and heat energy are often generated as a result of energy transformation. As these forms of energy are difficult to reuse, they are called waste energy. Efficient transformations produce less waste energy.

## Law of conservation of energy

If all the input energy could be added up and compared with all the output energy, it would always be the same. The total energy remains constant, but the type of energy will change – what goes in must come out!

This is considered the law of conservation of energy. No energy can be created or destroyed. The energy at the end must be equal to the energy present at the beginning. When you lift an object up in the air, you are adding gravitational potential energy. This energy did not just appear. The kinetic energy of your hand was conserved and transformed into the gravitational energy of the object. When the object is dropped, the energy is not destroyed. The gravitational energy is once again transformed into kinetic energy.

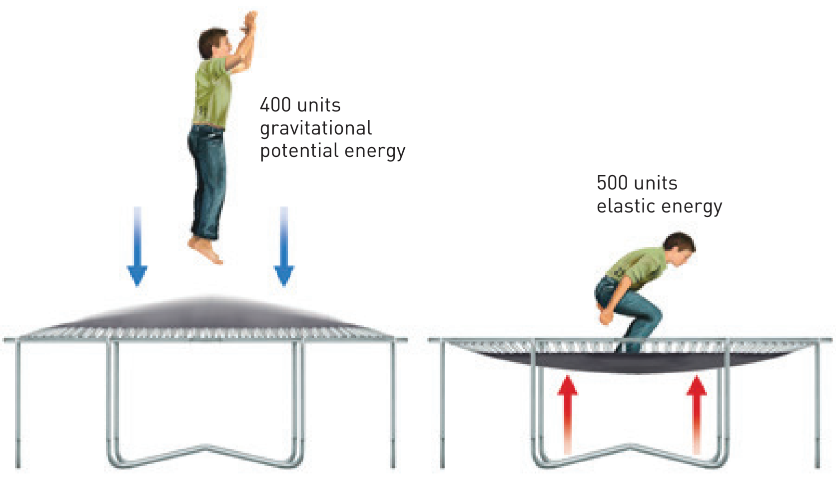



**Figure 3.32** Five hundred units of energy are stored in the springs of the trampoline. At the highest point, the jumper has 400 units of gravitational potential energy. Where have the 100 'missing' units gone?

## Energy efficiency

If a device like a trampoline transforms most of its input energy into the most useful output energy, then it is considered to be a very energy-efficient device. The less 'wasted' energy, the more energy-efficient the device. **Energy efficiency** is a calculation of the percentage of useful energy transformed.

$$\text{Efficiency} = \frac{\text{Useful energy output}}{\text{Energy input}} \times 100$$

Take the trampoline example in Figure 3.32. The input energy was 500 units and the useful output energy was 400 units. This means that the trampoline is 400 ÷ 500 × 100 = 80% efficient, which is not too bad. Most energy transformations for everyday appliances don't get this high. Scientists are constantly trying to design the best appliances possible with the highest efficiency ratings. This would make them better for the environment and cost less to power. Do you and your family always buy the most efficient appliances? Are you familiar with the star ratings on appliances? More stars mean that the appliance is more energy efficient. Not only is it good to know that less energy is being wasted, but it also means that, on your electricity and gas bills, you are paying for energy that is being used rather than for energy that is being thrown away.

EXPERIMENT 3.5: WHAT IF YOU BOUNCED A BALL?
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## Heat and sound waste energy

If no system is 100% efficient, but the energy cannot be destroyed, then where does the energy go? In most cases, the energy is transformed into heat and sound energy. Think what happens when you drop a ball on the ground. The ball starts with gravitational potential energy, which is transformed into kinetic energy when you drop it. When the ball hits the ground it makes a noise. The larger the noise, the more sound energy was generated. If you bounce a ball many times in a row, you might be able to feel the ball start to warm up. Heat energy is generated. Both the heat and sound energy dissipate into the air. They are not lost or destroyed. We cannot reuse them. They are by-products of the main energy transformation.

### Check your learning 3.5

#### Remember and understand

1 What is the law of conservation of energy?

2 The sun provides heat and light energy to our planet every day. If this energy is not destroyed, where does it go?

#### Apply and analyse

3 If you release a rubber band that had 10 units of elastic energy, 12 units of movement energy cannot be produced. Why not?

4 For the rubber band in question 3, what would its percentage efficiency be if 7 units of movement energy were produced? Where have the remaining 3 units of energy gone?

5 A student claimed energy was lost when she bounced a ball. Was she correct?

6 What are the by-product energy transformations for a car?

//SCIENCE AS A HUMAN ENDEAVOUR//

# 3.6 Energy efficiency can reduce energy consumption

*Knowledge and understanding of energy transformations is not just limited to scientists. A variety of people use this knowledge in their everyday lives.

## Using electricity

A hair dryer has two basic components: a fan and a heating element. When plugged in and switched on, the fan motor spins and the heating element heats up. So, a hair dryer converts electrical energy into thermal energy and kinetic energy. The air blown by the fan is directed over the heating element, passing the heat energy to the air, which flows out of the hair dryer. Some hair dryers have different speed and heat settings that control the amount of electrical energy flowing to each part of the device.

Other heating devices, such as toasters, also use heating elements to convert electrical energy into heat energy. Heating elements are made of certain types of wires that heat up without melting when electricity flows through them. The thermal energy is then passed to the air, which then passes the heat to the bread, toasting it.

Microwave ovens cleverly convert electrical energy into microwaves, which heat our food. Electric ovens are like oversized toasters and can have a fan in them, as does a hair dryer. Gas ovens and stoves use the chemical energy of the gas to produce heat by burning the gas. The more efficient this transformation, the less energy is wasted.

## Heating and cooling your house

No doubt your house has some sort of heating or cooling system, depending on where you live. You probably use electricity or gas to do this. In a hot environment, energy is needed to remove the heat from inside your home, allowing it to cool down. The warm air inside the house is moved over cool pipes in the air conditioner. The thermal energy of the house air is passed to the refrigerant inside the pipes and then is carried outside the house. If the house is well designed, then the thermal energy remains outside and the house stays cool.

Architects design homes to help control the flow of thermal energy. They can add a variety of features that help limit the amount of heating or cooling your house needs.

**Figure 3.33** Insulation prevents heat energy being transferred between the inside and the outside of the house.

## Insulation

Lining the inside of the walls, floors and roof of your house can make sure that the heat is not transferred between the outside air and the inside of the house. This means you will keep the heat inside on a cold day, and outside on a hot day.

## Window awnings

One of the main places heat is transferred is through a window. On a hot day, the light and heat from the Sun easily penetrate a window.

**CHALLENGE 3.6:** DESIGN AN ENERGY EFFICIENT HOUSE
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This transfers the heat into the house. An awning on a window can limit this. Limiting the number of windows facing the Sun can also help prevent the heat being transferred into the house.

## Veranda

A veranda works much like an awning, but it also prevents the heat and light from the Sun from shining on the walls. This prevents the heat from being transferred to the walls, and then to the air inside.

## Extend your understanding

1 Draw flow diagrams for the energy transformation process that happens in your house for:
   a heating during winter
   b cooling during summer.
2 A refrigerator cools the food inside it.
   a How do you think it does this?
   b Suggest possible energy transformations that may occur in a refrigerator.
3 How does an architect use their knowledge of energy efficiency?
4 How do window awnings and verandas keep a house cool in summer?
5 The temperature inside and outside a house was measured over 24 hours and displayed in Figure 3.34. From the graph, determine if the house was insulated. Give evidence to support your answer.
6 Study Figure 3.35, which shows how much energy is used by different household appliances.
   a Which appliance uses the most energy?
   b The clothes dryer uses more energy than the electric blanket. Use energy transformations to explain why.
   c Many people switch their appliances off at the wall rather than use the standby function (where the television is still on but the screen is dark). Use energy efficiency to explain possible reason for this.

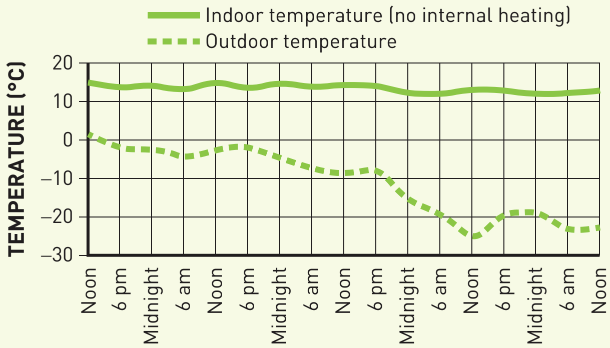


Figure 3.34

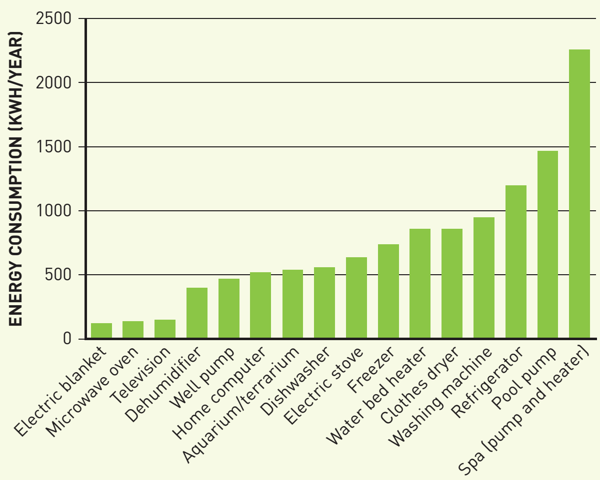


Figure 3.35

//SCIENCE AS A HUMAN ENDEAVOUR//

# 3.7 Solar cells transform the Sun's light energy into electrical energy

A solar cell is any device that transforms the Sun's light energy into electrical energy. The number of households using light energy to heat water or power heating and cooling devices is growing rapidly every year. Eventually we may even use cars powered by solar energy to drive to school.

## Using solar energy in Australia

Australia is often known as the sunburnt country. This is a reference to the large number of hours each day that the Sun shines. Australia is a big country and the number of hours varies greatly depending on the location and the time of year. Solar energy is often measured in the number of peak sunlight hours every day (see Figure 3.36). This is then averaged out over the whole year. For example, in the Hunter Valley in New South Wales, the number of peak hours can be as low as 4.0 hours/day in winter and as high as 6.5 hours/day in summer. Over a year this averages out to 5.6 hours/day. In Tasmania the average number of peak hours is 3 hours/day. In Queensland, Northern Territory and Western Australia, the average number of peak hours each day is 6.

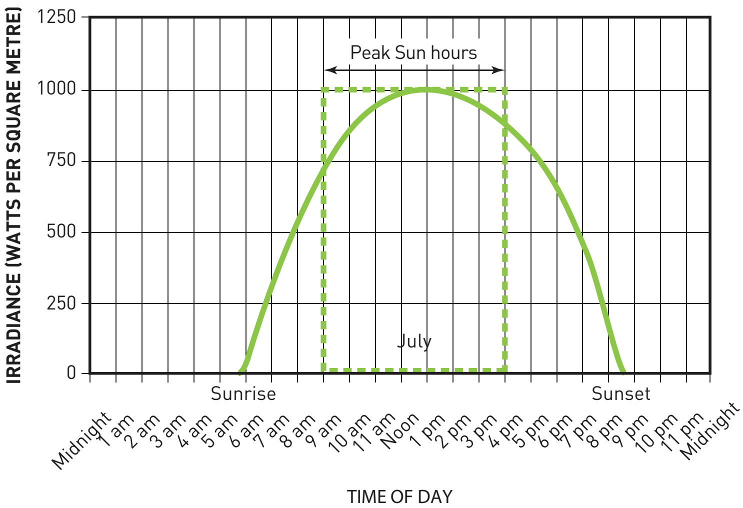


Figure 3.36


## Converting light energy into chemical potential energy

Using light energy to power a house has its problems. The most common time people use electrical energy is not during the time that the light energy is available. This means the light energy often needs to be stored so that it can be used at night. The light energy is transformed into potential chemical energy in a battery so that it can be used to heat water, provide light or make energy for cooking.

## Capturing the light energy

Solar panels are a collection of solar cells called **photovoltaic cells (PVCs).** When light shines on the surface of these PVCs, the light energy is transformed into electrical energy. The most efficient PVCs currently convert 30 per cent of the energy they receive from the Sun.

## Solar cars

Most current solar-powered vehicles only carry one person. They are lightweight (approximately 600 kg) so that they are more energy efficient. Although using a solar car for your everyday travel is not currently practical, with more research it may be in the future.

**CHALLENGE 3.7:** DURING WHAT TIME OF THE DAY DOES THE SUN PRODUCE THE MOST ENERGY?
GO TO PAGE 174.

**1883**
First solar cell invented by Charles Fritts. Solar cell = selenium (semiconductor) with a thin layer of gold.

**1941**
Silicon solar cell invented by Russell Ohl has efficiency of 1%.

**1954**
Gerald Pearson, Calvin Fuller and Daryl Chapin improved the efficiency to 6%. Silicon strips were used to create the first solar panels.

**1955**
The first solar car invented was a tiny 35 cm vehicle created by William G. Cobb of General Motors.

**1962**
International Rectifier Company designed the first solar car that could be driven.They converted a vintage 1912 Baker electric car to run on approximately 10 640 PVCs.

**1977**
Alabama University professor Ed Passerini constructed his own solar powered car called 'Bluebird'.

**1980**
Englishman Alain Freeman road-registered a 3-wheeler solar car with a solar panel on the roof.

**1980**
Arye Baunstein and colleagues at Tel Aviv University (Israel) designed a solar car with a solar panel on the roof and hood of the car. The car was recorded reaching 65 km/h with a top speed of 80 km/h.

**1982**
Larry Perkins and Hans Tholstrup constructed and drove the 'Quiet Achiever', a home-made vehicle, from the east coast of Australia to the west coast. Their feat is recognised in the World Solar Challenge, a solar car race that allows solar car designers to compete in a race across Australia every two years.

**1987**
GM Sunracer completed a 3010 km trip in California with an average speed of 67 km/h.

**2014**
A solar-powered family car (with four seats) called 'Stella' was driven 613 km from Los Angeles to San Francisco.

1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010

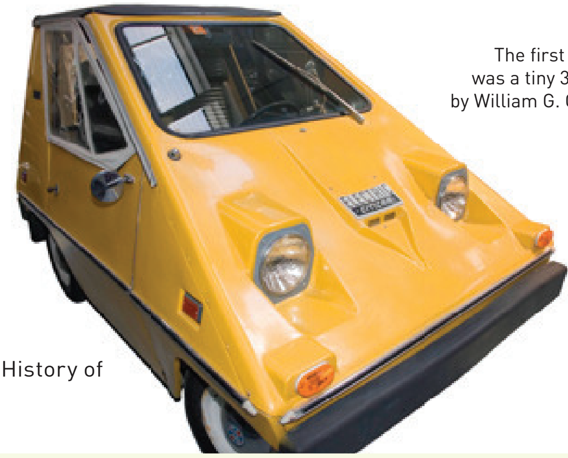

**Figure 3.37** History of solar cars.

## Extend your understanding

1 What advantages will solar cars have over petrol cars?
2 What do we call a cell that captures the light energy from the Sun?
3 Why does light energy often need to be stored as chemical energy before it can be used?
4 Use Table 3.1 to determine which city has the highest average amount of sunshine. How does this compare to your nearest city?
5 Research when the next World Solar Challenge will occur. How far is the race? Where does it start and finish?

**Table 3.1** Solar energy production in Australian cities.

| CITY | AVERAGE DAILY PRODUCTION OF 2 KW SYSTEM (kWh) |
|---|---|
| Adelaide | 8.4 |
| Alice Springs | 10.0 |
| Brisbane | 8.4 |
| Cairns | 8.4 |
| Canberra | 8.6 |
| Darwin | 8.8 |
| Hobart | 7.0 |
| Melbourne | 7.2 |
| Perth | 8.8 |
| Sydney | 7.8 |

//SCIENCE AS A HUMAN ENDEAVOUR//

# 3.8 Engineers use their understanding of energy to solve problems

Figure 3.39 Mechanical engineers work with forces and motion.

* The word 'engineer' comes from the Latin words *ingeniator* or *ingenium*, which literally mean 'ingenious one'. Engineers provide solutions, shape future developments and generate ideas that make life easier. All engineers are problem solvers, but some know how to solve specific problems better than others. People who study to become engineers often choose an area of interest and concentrate their skills in that field.

Figure 3.38 Water slides transform the gravitational potential energy of the water into kinetic energy. Reducing friction of the slide makes it more efficient.

## Chemical engineers

Chemical engineers combine existing materials and develop new materials. These materials can then help other engineers build structures. Chemical engineers would also consider where the materials come from, whether they were being used sustainably and how much energy is required to process and transport them.

## Mechanical engineers

Mechanical engineers deal with forces and motion – designing and improving things that have moving parts or have physical forces pushing or pulling them. This includes large structures such as water slides where the gravitational potential energy at the top is used to provide kinetic energy (speed) at the slide's base. Reducing the friction of the slide makes it more efficient, and therefore more of the potential energy will be transformed into kinetic energy (speed) at the base. Mechanical engineers have produced some of the most important and useful inventions in history including the zipper and the yo-yo!

## Electrical engineers

Electrical engineers design and organise electrical equipment. This equipment may be used for satellites, computers and medical equipment. They are also involved in developing electricity supplies, including the development of alternative energy sources.

## Civil engineers

Civil engineers research, plan and design structures. They know about the physical properties of materials. They are interested in how different materials perform under different conditions. For example, tall buildings need to remain secure in high winds.

**EXPERIMENT 3.8:** INVESTIGATING STRUCTURES AND MATERIALS USING ICY POLE STICKS
GO TO PAGE 175.

**CHALLENGE 3.8:** LEAKYWATER COUNCIL SWIMMING POOL AND WATERSLIDE
GO TO PAGE 176.

## Evaluating a proposal

When engineers design and evaluate different options for a project there are three main points to consider.

1 Will the option do the job it is expected to do?
2 How well does the option do that job? Is there a better way?
3 Is the option cost-effective?

Other points also need to be considered, such as how long each option will take to build, cost, availability of materials and impact on the environment.

The simplest way to compare different options for a project is to use a **cost–benefit analysis**. In a cost–benefit analysis, an engineer makes a list of all the impacts of each option, such as the benefits to the community, potential profits to the owner and the environmental impacts. These are then compared to the cost of each option. When all the options have been analysed in this way, the engineer can more easily compare the options and decide which one is best. The best option would have the most benefits and the least costs.

Projects are designed and evaluated using many different **criteria.** Appropriate criteria include all the aspects you want to design for and measure. Engineers need to assess many aspects of each project before, during and after its completion. The design and assessment process aims to ensure that each project is the best option that fulfils all the criteria needed.

There are many examples of engineering assessments.

- **Social impact assessment** – Will the project have a good or bad impact on people's lives?
- **Risk assessment** – What might happen if the project fails?
- **Environmental impact** – What impacts will it have on the environment?
- **Contamination assessment** –Will any chemicals used in the project contaminate living things?
- **Strength and facility life assessment** – What sort of loads will the structure need to withstand? How long will a structure survive?
- **Geotechnical hazard assessment** – Will there be any problems with digging the soil?

Most engineering companies use criteria assessments to work out the best way to proceed with a proposal.

### Extend your understanding

1 Write a definition of 'engineering'.
2 What is the difference between civil engineers, electrical engineers, chemical engineers and mechanical engineers?
3 What are some reasons to build a prototype of your design before finalising the project?
4 What type of criteria might be considered by an engineer before starting a project?
5 What would be the social impact of a water slide?

* REVIEW

# 3

## Remember and understand

1 Match these words and phrases with their correct meanings:

| WORD/ PHRASE | MEANING |
|---|---|
| Kinetic energy | The energy stored in a compressed spring. |
| Nuclear energy | Another name for stored energy. |
| Potential energy | The energy of an object when lifted up. |
| Elastic energy | Used widely throughout the world to generate electricity from atoms. |
| Gravitational energy | Possessed by all moving objects. |

2 Are the following true or false? For false statements, rewrite them to make them correct.
- a Springs only hold stored energy when they are stretched.
- b When an object is thrown up in the air it gains gravitational potential energy.
- c Sound energy is a type of potential energy.
- d Petrol contains nuclear energy.

3 What is the main form of energy in each of the following situations?
- a Water flowing slowly over a waterfall.
- b A rollercoaster at the lowest point of the ride.
- c The Sun coming in through a window on a sunny day.
- d A boy riding his skateboard.
- e A stretched rubber band.

4 Name a device that transforms:
- a electrical energy into light energy
- b elastic energy into kinetic energy
- c electrical energy into sound energy
- d gravitational energy into electrical energy
- e kinetic energy into electrical energy.

5 Why might you employ a chemical engineer if you were designing a new clothing range?

## Apply and analyse

6 Use numbers in an example of your own to explain the law of conservation of energy.

7 Use numbers in an example of your own to explain energy efficiency.

8 What is the percentage efficiency of a device if it transforms:
- a 20 units of input energy into 12 units of useful output energy?
- b 600 units of input energy into 500 units of useful output energy?
- c In (a) and (b) above, where did the other energy (i.e. 8 units in (a) and 100 units in (b)) go?

9 The main job of a car travelling on the road is to produce kinetic energy in its wheels. What other parts of a car may demonstrate kinetic energy?

10 Think of your day today. How many different energy forms have you come across, possessed, used or witnessed? List them in order of use during the day. Which one was the most common and why?

11 Visit a local playground and examine the play equipment. Take a digital photo or draw a picture of a piece of equipment and work out what types of energy are demonstrated as a child plays on the equipment.

12 List the places and structures in your school that you think an engineer was involved with. Justify your decisions.

## Evaluate and create

13 Energy comes in many different forms. Create a poster that illustrates each type of energy with visual examples.

14 The massive earthquake and tsunami in Japan in March 2011 caused extensive damage to the Fukushima nuclear power plant, north of Tokyo, and created an emergency situation. Research this disaster and present a 2 minute news report to the class that highlights the issues surrounding the use of nuclear energy.

15 Energy types rarely exist alone. They are always on the move, making things happen. Think about some of the things energy can do. For at least two of these, identify the

type or types of energy involved. If more than one type of energy is involved, link the different types with arrows. Try to include as many different scenarios as you can.

## Research

16 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

a **Compact fluorescent lights**

How do compact fluorescent lights (CFLs) work? How do they differ from fluorescent light globes? Why are CFLs initially more expensive to buy, but then more economical over time? What is the benefit of using CFLs?

b **Energy-efficient housing**

In previous societies, energy efficiency was important because people had limited access to the types of energy supplies and their applications that we have today. Research how civilisations in tropical areas designed their homes to keep them cool and damp free. What types of energy-efficient practices have humans used through the ages?

c **New and specialised engineering fields**

Select one of the newer fields of engineering like aerospace, biomedical or nuclear engineering. What does the engineer in that field do? What do they need to know? Who do they work with? Where do they work? What materials do they work with? Name a significant project the engineer has worked on.

d **Plastic bank notes**

Investigate the history of how Australia used chemical engineering to develop plastic bank notes. Who did this work? Why did they do this? What problems were encountered? What are some of the features of our plastic bank notes?

# 3

## * KEY WORDS

**chemical potential energy**
energy stored in chemicals, e.g. in food, fuel or explosives; also known simply as chemical energy

**cost–benefit analysis**
list of the costs compared with the benefits; usually performed to analyse a proposed engineering project

**criteria**
the important aspects of a project that need to be measured; designed to make sure each project is as good as it can be

**elastic potential energy**
energy stored through stretching or squashing, e.g. in a stretched spring or rubber band

**electrical energy**
energy associated with electric charge, either stationary (static) or moving (current)

**energy efficiency**
measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy, e.g. 90% efficiency is very good

**gravitational potential energy**
energy stored due to the height of an object, e.g. a child at the top of a slide

**kinetic energy**
energy of motion or moving objects

**law of conservation of energy**
scientific rule that states that the total energy in a system is always constant and cannot be created or destroyed

**nuclear energy**
energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much, much larger than the chemical energy released in chemical reactions

**photovoltaic cells (PVCs)**
an electrical device that converts light energy into electrical energy, *see* solar cells

**potential energy**
energy stored in objects and waiting to be used, e.g. gravitational potential energy

**remote control**
electronic device used for the remote operation (i.e. at a distance) of a machine

**solar cell**
used to transform sunlight directly into electrical energy; usually in the form of a panel; also known as a solar panel

**sound energy**
type of kinetic energy made when things vibrate

**thermal energy**
scientific term for heat energy

**transferred**
said of energy that has moved from one object to another

**transformed**
changed one form of energy into another form of energy