

Energy and change

A project funded by the Nuffield Foundation

Theme I

How much energy?

Theme I - How much energy?

What is this theme about?

All the previous themes have been concerned with the *direction* of change. In this theme, we are concerned with how big the changes are. Here are two questions:

Can you bring a saucepan of cold water to the boil using an ice cube?

Can you bring a saucepan of cold water to the boil using a burning match?

The answer to both of these questions is 'no', but for different reasons. In the first case it is because energy flows, but in the wrong direction. In the second case, energy flows in the right direction but not enough to do the job.

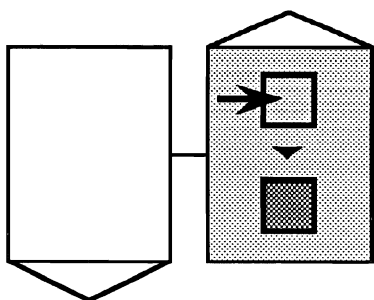
Energy can be measured. We can talk about how much energy is transferred when we boil a saucepan of cold water. Energy puts constraints on what is possible. In the first part of the theme, there are activities which are intended to give pupils a 'feel' for the amounts of energy, and rates of energy flow involved in various changes. In the second part of the theme, these ideas are put to use in working out fuel costs in everyday situations - for example, keeping a home warm or running a car. Extensive use is made of tables and charts, so there is virtually no need for any calculation in this work.

The activities

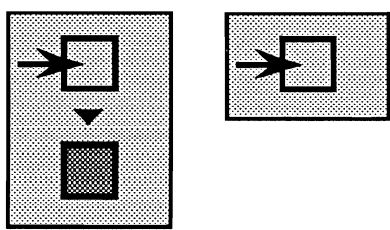
- I1 A ladder of fuels
- I2 Comparing energy values
- I3 Amounts and rates
- I4 Working out fuel costs
- I5 Hot water in your home
- I6 Keeping your home warm
- I7 Using electrical appliances
- I8 Running a car

Conventions used in this theme

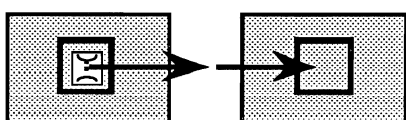
The activities are illustrated by 'pictures of changes' which have been introduced in earlier themes. They are intended to allow helpful connections to be made between qualitative and quantitative ideas, but a previous understanding of these pictures is not essential to understanding the activities in this theme. Many of these pictures were introduced in Theme H 'Fuels and food', for example:



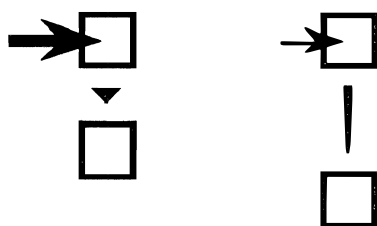
Things do not get hot 'just by themselves'.
They need to be driven by some other change.



In this theme, we are concerned with *amounts* and *rates* of energy flow, rather than *direction* of change. Many of the pictures, therefore, do not show whether the change 'just happens' or not, or the 'after' picture.



In this theme, we shall also be paying attention to energy transferred from one system to another.



High rate
Short period of
time

Low rate
Long period of
time

Different rates of energy flow and periods of
time are indicated by different sized arrows.

Activity I1 - A ladder of fuels

This activity is about looking quantitatively at changes involving burning fuels and making things hot. The aim is to introduce the idea that energy can be measured, and to give pupils a 'feel' for the sizes of the units used.

Energy can be measured. We can talk about how much energy is transferred when we boil a saucepan of cold water. Energy puts constraints on what is possible.

When a hot cup of tea cools it warms the room. Could a hot cup of tea be sufficient to keep a house centrally heating for a year? Clearly not. But would a thousand do the job? Or a million? Or a billion? Knowing the amounts of energy involved would help us answer these kinds of questions.

Sheet 1 gives some background information. On Sheet 2, there are two sets of pictures. The first set of pictures is about fuels, and the second set is about heating jobs. The pictures should be ordered according to their guesses about the amount of energy transferred.

After checking their answers, they can write them down on the ladder on Sheet 3, which also shows actual amounts of energy involved in kJ. (Kilojoules could be related to energy values on food labels.) The purpose is to give a 'feel' for the amounts of energy involved (measured in kJ). They can also make comparisons across each 'rung'. This is taken up further in activity I2 'Comparing energy values' for a wider range of kinds of change.

Answers:

a large tree	F	100 000 000 kJ	A	heating a house for a year
6 sacks of coal	A	10 000 000 kJ	E	hot water for a family for a year
a large can of paraffin	D	1 000 000 kJ	B	heating a flat for a week
a wooden chair	C	100 000 kJ	D	making 3 cups of tea a day for a year
a bottle of meths	I	10 000 kJ	G	hot water for a bath
a candle	E	1 000 kJ	I	heating a large saucepan of water till it boils
a wooden pencil	H	100 kJ	C	making one cup of tea
some petrol in a dropper	B	10 kJ	F	evaporating one drop of water
a match	G	1 kJ	H	melting one ice cube

In ordering the pictures, pupils may pay attention to rates as well as amounts of energy transfer. For example, they may consider putting some petrol in a dropper above a candle because it would burn faster. This can provide a useful discussion point for ideas about amounts and rates which are developed in Activity I3.

Activity I2 - Comparing energy values

This activity extends the range of the kinds of changes which can be compared quantitatively.

The kinds of changes involve fuels, food, moving things, electricity, light and making things hot. Sheet 1 gives some background information. The changes to be put in order are shown on Sheet 2. Because there are only four 'rungs' on each ladder, it is probably not worth cutting up slips of paper to order - pupils can write their guesses in the boxes before checking their answers. Sheet 3 shows the changes in the correct order. Whereas in activity 1, it is in general not difficult to put the changes in an approximate order, thinking about the order here is more challenging. It is intended to stimulate discussion about why the changes are in the order they are. For example, why is 'using an electric fire for 3 hours' higher up the ladder than 'using a TV for 5 hours'? Many pupils may initially pay attention only to the time involved. This activity therefore makes us think about rates and amounts more explicitly than the previous activity.

On Sheet 4, there are questions about making comparisons across the 'rungs' of the ladder. Some may seem surprising and are worth discussing - e.g. relating a car travelling to amount of fuel, or walking to amount of food.

Answers:

	Fuels	Food	Releasing things pulled apart	Moving things	Using electricity	The Sun	Making things hot
10 000 kJ	C	B	A	D	A	C	B
1 000 kJ	A	D	C	B	C	D	D
100 kJ	B	A	D	A	B	B	C
10 kJ	D	C	B	C	D	A	A

Activity I3 - Amounts and rates

This activity introduces units for measuring rates of energy transfer or power, and gives pupils some experience in getting a feel for the sizes of units of energy and power.

Sheet 1 is intended to be used as an OHP to introduce the distinction between energy and power. The examples used (hot water for bath, car, keeping a room warm) are taken up in the later activities about the 'case-studies'.

In the previous two activities, energy was measured in units of kJ. This is a convenient unit for laboratory use, but rather small for use on domestic fuel bills, which use the kWh instead. (Electricity bills have always shown this; gas bills have recently started to use this unit as well.)

This activity therefore introduces the kWh as another unit for measuring energy. All the remaining activities in this theme use kWh as the unit of energy.

Pupils will need Sheet 2 which has the instructions for the activity, and Sheets 3 and 4 which give ladders of energy and power in order for them to get a 'feel' for the size of a kWh and a kW. After they have made estimates of the values on Sheet 2, they can be given Sheets 4 and 5 in order for them to check their answers.

Sheet 7 is an information sheet which gives a more detailed discussion of the units of energy and power, and how they may be calculated.

Activity I4 - Working out fuel costs

In this activity, pupils can work out the costs for various jobs which require fuel. They are introduced to the use of a chart to do this, which is similar to the way in which all the later charts in this theme are used.



It would be worth introducing the activity by looking at some examples of fuel bills (gas and electricity) and noting what is shown on them. The chart in this activity is based on the following prices per kWh: electricity (standard rate) 4.0p, electricity (economy rate) 7.3p, gas 1.5p, petrol 5.8p.

The chart has been constructed in such a way that it is possible to work out the cost for a very wide range of energy values (logarithmic scales have been used). Pupils need to be given some guidance about how to read the scales on the chart, in particular how to use the multiplying factors x1, x2, x5. Most pupils are able to use the scales without difficulty once they have had some practice. It does need to be stressed that the chart can only be used to make estimates, since it is not possible to read accurately off the scales. Therefore they should not worry too much about exact values.

Activities I5, I6 and I7 - Energy in the home

Activities I5, I6 and I7 are all about domestic energy use, and all use the chart from this activity to estimate domestic fuel costs. The following background information puts this in context.

These are the main uses for energy in the home:

Electrical	1 lighting and other appliances		
Heating	2 cooking	 higher temperatures	more energy (more to heat) 
	3 hot water		
	4 space heating		

Electrical: lighting and many other appliances, often with electric motors

Heating: This could be done with a range of fuels, including electricity. There are three things that we want to heat. In one house, there may be different fuels for each use.

Cooking - this needs to be done at high temperatures (for example, a typical oven temperature is around 350°C)

Hot water - this needs a medium temperature (the water we use for washing feels comfortable at about 60°C)

Space heating (heating rooms) - this needs a fairly low temperature (a warm living room might be around 22°C)

Though rooms need to be heated only to quite a low temperature, it costs a lot because there is a lot to heat.

Cooking needs much higher temperatures, but is a much smaller part of the fuel bill. There is much less to heat.

All of these costs, with the exception of the fuel used for cooking which is relatively small, can be worked out in the next three activities, so it is possible to arrive at the total cost of domestic fuel.

Activity I5 - Hot water in your home

This activity is about working out the cost of domestic hot water. It is concerned with the amounts of energy required to make things hot.

Sheet 1 gives some background information, and explains how to use the other sheets to work out the cost. Sheet 2 gives a worked example with two other examples for pupils to work out.

Sheet 3 shows a chart which relates the energy needed to make water hot to the daily hot water consumption and the period of time used. Domestic hot water is normally in the range 55°C - 65°C. The chart here assumes that the temperature of water is raised from 15°C - 60°C and also assumes that no energy escapes (1 litre of water requires about 190 kJ - calculated from $1 \text{ kg} \times 4.184 \text{ kJ kg}^{-1} \text{ }^{\circ}\text{C}^{-1} \times 45^{\circ}\text{C}$ - which is approximately 0.05 kWh).

Sheet 4 shows a chart which relates the total energy needed to the energy input to make water hot and the effectiveness of the insulation. This includes both the insulation of the tank and the boiler efficiency - typical efficiencies are in the range 30-70%.

Activity I6 - Keeping your home warm

This activity is about working out the cost of keeping a house or a flat at a higher temperature than the air outside. It is concerned with the rate at which energy escapes, which depends on the level of insulation and the temperature difference.

Sheets 1 and 2 give some background information, and explain how to use the other sheets to work out the cost. Sheet 3 gives a worked example with one other example for pupils to work out. They could also try to estimate the cost of keeping their own home warm.

Sheet 4 shows some tables from which the 'energy leakage factors' can be found. These are commonly called U values, and more detailed values can be found in many DIY books and books on home central heating. U values are the rate at which energy passes through a material with unit area through a temperature difference of 1°C . They are measured in units of $\text{W}^{\circ}\text{C}/\text{m}^2$. In planning a central heating system, it is necessary to know the rate at which energy escapes from all of the rooms in the home, in order to install a radiator with the appropriate output to balance the energy escaping. The term 'energy leakage factor' has been coined here to emphasise what it is that is being measured. Note too, that the activity talks about energy 'leakage' rather than energy 'loss' - 'loss' may imply that the energy 'disappears'.

Sheet 5 shows a chart which relates the rate at which energy leaks out to the level of insulation of the home (energy leakage factor) and the temperature difference between the inside and outside. It is calculated by multiplying the energy leakage factor by the temperature difference.

Sheet 6 shows a chart which relates the total energy needed to the rate at which energy leaks out and the period of time. It is calculated by multiplying the rate by the time (note that, apart from the labels, this chart is identical to the chart used for electrical appliances in Activity I7).

Activity I7 - Using electrical appliances

This activity is about working out the cost of using domestic electrical appliances. It is concerned with how the total energy flowing through these appliances depends on the rate at which energy flows and the period of time.

Sheet 1 gives some background information, and explains how to use the other sheets to work out the cost. Sheet 2 gives two worked examples with other examples for pupils to work out.

Sheet 3 shows some tables of power ratings of electrical appliances, and a table relating daily to annual usage.

Sheet 4 shows a chart which relates the total energy passing through electrical appliances to the power rating and the time used. Note that, apart from the labels, this chart is identical to the chart used for keeping a home warm in Activity I6. The situations - for example, a central

heating system and an electric drill - are in fact rather similar. The central heating system must maintain the rooms at a temperature above the surrounding air - the energy input is balanced by the energy flowing from the warm house to the cooler surroundings. The electric motor maintains the drill in a steady state - keeping it moving and keeping it at a temperature above the surrounding air. The energy input is balanced by the energy flowing from the warm drill to the cooler surroundings.

Activity I8 - Running a car

This activity is about working out the cost of the fuel used for a car journey. It is concerned with the energy needed to get something moving and to keep it moving, and the efficiency with which energy is transferred from the burning fuel.

Sheet 1 gives some background information, and explains how to use the other sheets to work out the cost. Sheet 2 gives a worked example with two other examples for pupils to work out.

Sheet 3 shows a chart which relates the energy output of the engine to the speed and distance of a car journey. The power output from an engine is not directly proportional to the speed (if it were then the energy used for a journey would be independent of the speed - e.g. double the power, but half the time). The power is proportional to the square of the speed, so the faster the car goes the more the energy output is required for a journey.

However, this is not the only factor. If it were, then fuel economy would be best at the lowest speed possible. The efficiency of the engine decreases at low engine speeds, mainly because of the energy which escapes as the exhaust gases are pushed out of the cylinder. Sheet 4 shows a chart which relates energy input to the energy output needed and the speed of the car.

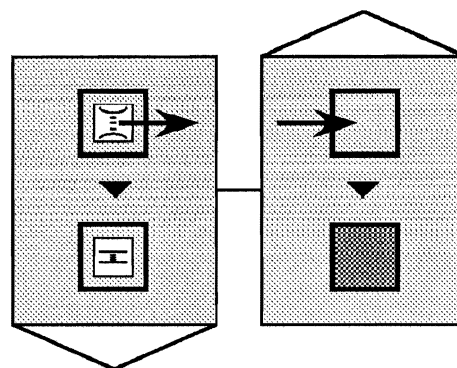
In examples 2 and 3, the effects of engine efficiency on fuel consumption can be compared. For example 2, the energy needed to get the car moving at 10 mph is 0.003 kWh, and the energy needed to keep it moving at this speed for 100 miles is about 7 kWh. The energy needed to keep the car moving is much greater than the energy to get it moving, so the total energy output required from the engine is 7 kWh. At 10 mph, the energy input required is 300 kWh (the engine efficiency is only about 2.5% at this speed), and the cost is about £17.

For example 3, the energy needed to get the car moving at 50 mph is 0.13 kWh, and the energy needed to keep it moving at this speed for 100 miles is about 18 kWh. Again, the energy needed to keep the car moving is much greater than the energy to get it moving, so the total energy output required from the engine is 18 kWh. Notice that the energy output is greater at 50 mph than at 10 mph. At 50 mph, the energy input required is 90 kWh (much less than at 10 mph since the engine efficiency is much greater at about 20%), and the cost is about £5.

Why do we need fuels?

The main uses of fuels are to make things hot or to make things move.

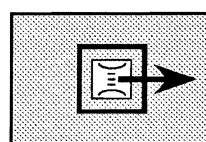
Things do not get hot or start to move by themselves. This is the reason we need fuels.



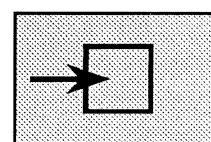
Measuring energy

We need enough fuel to do the job. For example, a burning match would release enough energy to heat the water for a bath. Would a candle?

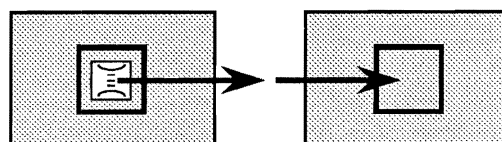
To compare different 'jobs', it is useful to measure the amount of energy. Energy is measured in J and kJ (Joules and kilojoules).



energy from
burning fuel



energy needed to
make something hot



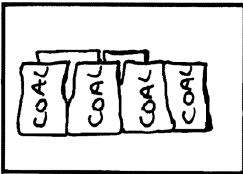
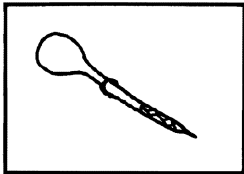
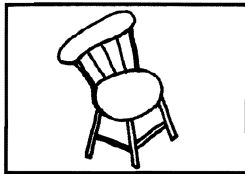
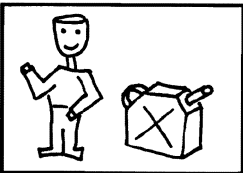
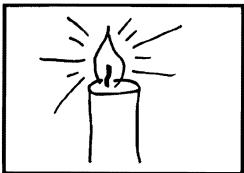

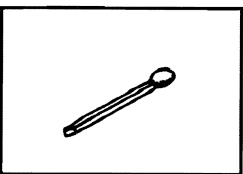
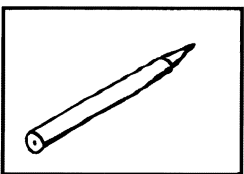

energy transferred from burning fuel
to make something hot

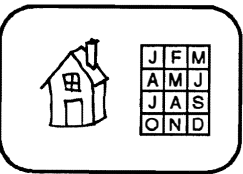
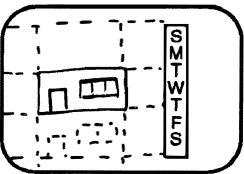
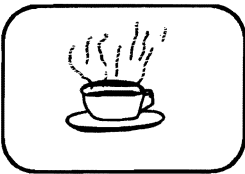
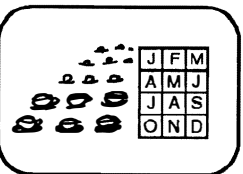
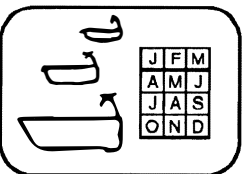
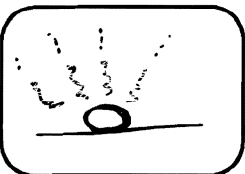
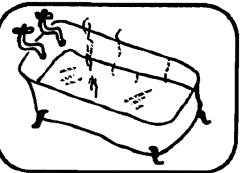
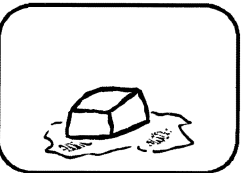
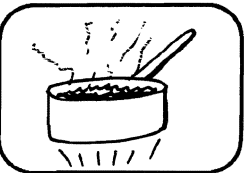
Instructions

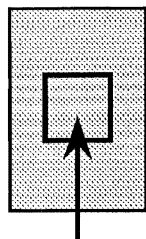
- 1 On the next sheet, there are two sets of changes. The first set is about things being burned. The second set is about making things hot.
- 2 Put the first set of changes in order, with the one in which most energy is released at the top.
- 3 Now put the second set in order, with the one needing most energy at the top,.
- 4 After you have checked your order, write the results on the 'fuels ladder' sheet.

Questions

- 1 Could you use a burning candle to heat the water for a bath?
- 2 What could a burning match do?

<p>A</p>  <p>6 sacks of coal</p>	<p>B</p>  <p>some petrol in a dropper</p>	<p>C</p>  <p>a wooden chair</p>
<p>D</p>  <p>a large can of paraffin</p>	<p>E</p>  <p>a candle</p>	<p>F</p>  <p>a large tree</p>
<p>G</p>  <p>a match</p>	<p>H</p>  <p>a wooden pencil</p>	<p>I</p>  <p>a bottle of meths</p>

<p>A</p>  <p>heating a house for a year</p>	<p>B</p>  <p>heating a flat for a week</p>	<p>C</p>  <p>making one cup of tea</p>
<p>D</p>  <p>making 3 cups of tea a day for a year</p>	<p>E</p>  <p>hot water for a family for a year</p>	<p>F</p>  <p>evaporating one drop of water</p>
<p>G</p>  <p>hot water for a bath</p>	<p>H</p>  <p>melting one ice cube</p>	<p>I</p>  <p>heating a large saucepan of water till it boils</p>



Energy going to
the room being heated

100 000 000 kJ

10 000 000 kJ

1 000 000 kJ

100 000 kJ

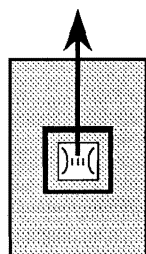
10 000 kJ

1 000 kJ

100 kJ

10 kJ

1 kJ



Energy coming from
burning fuel

Comparing energy values

Sheet 1

We can measure the energy involved in many different kinds of change. Some examples are shown below.

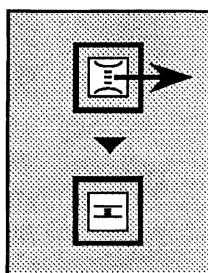
Instructions

- 1 On the next sheet, there are some sets of changes. Put them in order of the amount of energy involved (highest at the top). Write the letters in the boxes.
- 2 After you have checked your answers, you can use this 'ladder' to compare energy values. Answer the questions on the question sheet.

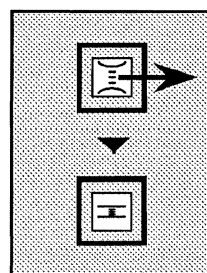
Releasing energy

Burning a fuel releases energy.
So do foods 'burnt' in the body.

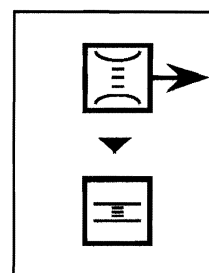
Things that have been 'pulled apart' also release energy when you 'let go'.



fuel



food

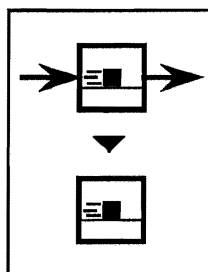


releasing things
pulled apart

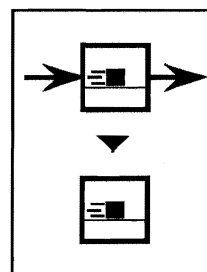
Energy on the move

Energy is needed to make things move.

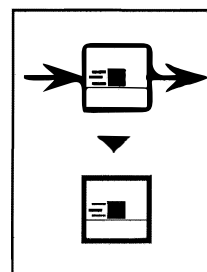
Energy can be moved from one place to another by electricity and by radiation (e.g. light).



moving



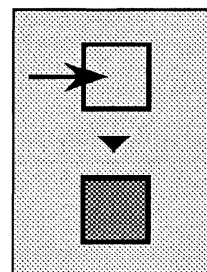
electricity



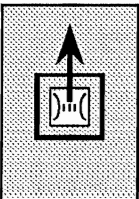
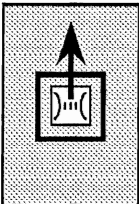
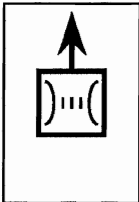
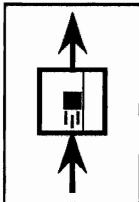
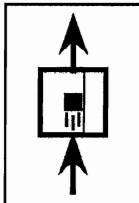
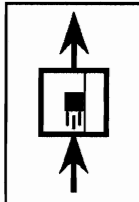
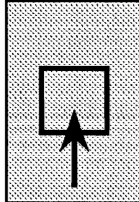
radiation

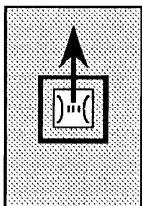
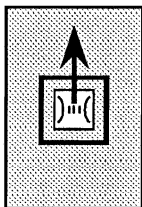
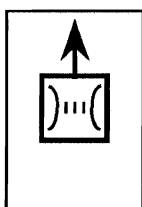
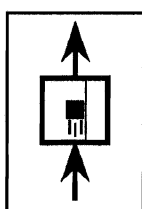
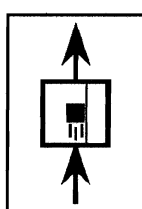
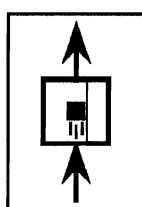
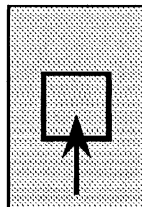
Making things hot

Energy needs to be put into things to make them hot.



making
something hot

Fuels	Food	Releasing things pulled apart	Moving things	Using electricity	The Sun	Making things hot
						
A a candle	A a biscuit	A a 'fist-sized' meteorite falling from outer space	A a car travelling 200 yards	A using an electric fire for 3 hours	A sunlight shining on a person for 20 seconds	A evaporating one drop of water
B a wooden pencil	B a loaf of bread	B releasing 1000 stretched elastic luggage cords	B walking 5 miles	B using a light bulb for half an hour	B sunlight shining on a small plant for 20 minutes	B hot water for a bath
C a bottle of meths	C a spoon of milk	C a tonne of water flowing down a 100 metre high hill	C walking 100 yards	C using a TV for 5 hours	C sunlight shining on a house for 2 minutes	C making one cup of tea
D some petrol in a dropper	D a packet of crisps	D a car falling from the height of a house	D a car travelling 10 miles	D using an electric fire for 10 seconds	D sunlight shining on a person for half an hour	D heating a large saucepan of water till it boils
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Fuels	Food	Releasing things pulled apart	Moving things	Using electricity	The Sun	Making things hot
						
10 000 kJ	a loaf of bread	a 'fist-sized' meteorite falling from outer space	a car travelling 10 miles	using an electric fire for 3 hours	sunlight shining on a house for 2 minutes	hot water for a bath
1 000 kJ	a packet of crisps	a tonne of water flowing down a 100 metre high hill	walking 5 miles	using a TV for 5 hours	sunlight shining on a person for half an hour	heating a large saucepan of water till it boils
100 kJ	a biscuit	a car falling from the height of a house	a car travelling 200 yards	using a light bulb for half an hour	sunlight shining on a small plant for 20 minutes	making one cup of tea
10 kJ	a spoon of milk	releasing 1000 stretched elastic luggage cords	walking 100 yards	using an electric fire for 10 seconds	sunlight shining on a person for 20 seconds	evaporating one drop of water

Questions

When you have constructed an energy ladder, you can use it to compare energy values.

1. Pick the things which have the same energy value, for example:

'The energy value of a biscuit is the same as that of sunlight shining on a small plant for 20 minutes (100 kJ).'

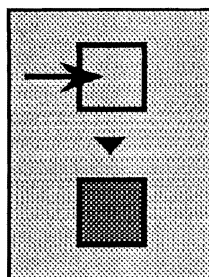
Now do the following:

- a) The energy needed to make a car move 10 miles is the same as ...
(use the column 'Making things hot').
- b) The energy value of a loaf of bread is the same as ...
(use the column 'The Sun').
- c) The energy value of a candle is the same as ...
(('Making things hot')).
- d) The energy to walk 100 yards is the same as ...
(('Food')).
- e) The energy needed to make one cup of tea is the same as ...
(('Moving things')).
- f) The energy flowing through an electric fire in 3 hours is the same as ...
(('Fuels')).
- g) The energy value of a bottle of meths is the same as ...
(('Using electricity')).
- h) The energy released when 1 tonne of water flows down 100 metres is the same as ...
(('Fuels')).
- i) The energy of sunlight shining on a person for 20 seconds is the same as ...
(('Moving things')).
- j) The energy needed to make the hot water for a bath is the same as ...
(('Food')).
- k) The energy flowing through a TV in 5 hours is the same as ...
(('The Sun')).
- l) The energy released from a falling 'fist-sized' meteorite is the same as ...
(('Making things hot')).

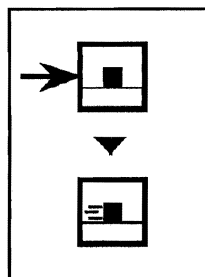
2. Did any of these surprise you? If so, explain why.

3. Try making up some more of your own.

Energy is needed to make things hot (e.g. a hot bath).



hot bath

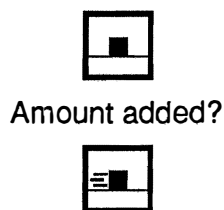
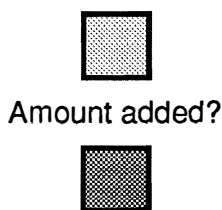


car

Energy is also needed to make things move (e.g. starting a car).

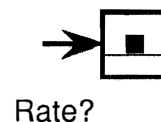
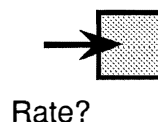
Sometimes we are interested in *amounts* of energy.

Energy is measured in kJ. Larger amounts of energy are measured in kWh (kilowatt-hour).

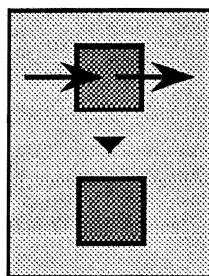


Sometimes we are interested in how *quickly* energy is flowing. The rate of energy flow is called 'power'.

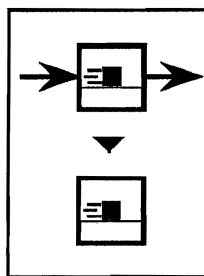
Power is measured in W and kW (watts and kilowatts).



Energy is needed to keep things hot (e.g. a centrally heated room).



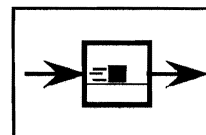
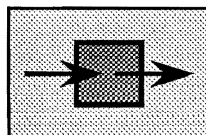
room



car

Energy is also needed to keep things moving (e.g. driving a car along a road).

It is often useful to know the rate (in W or kW) at which energy flows through things like this.



Sometimes we are interested in *amounts* of energy. Energy is measured in kJ. Larger amounts of energy are measured in kWh (kilowatt-hour).

Sometimes we are interested in *how quickly* energy is flowing. The rate of energy flow is called 'power'. Power is measured in W and kW (watts and kilowatts).

1 The following two sheets show a 'ladder of energy' and a 'ladder of power'. Look at these carefully to 'get a feel' for the sizes of the values.

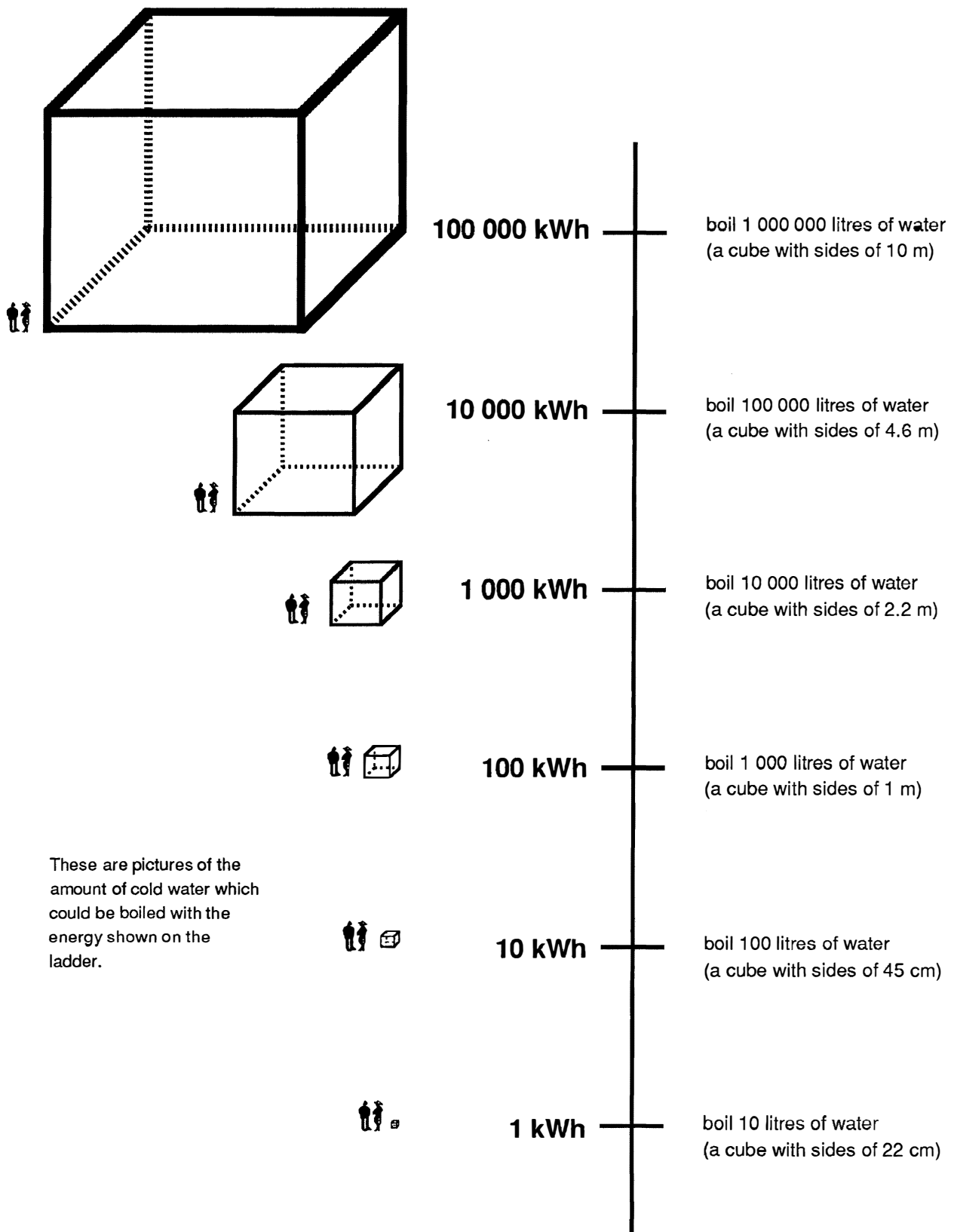
2. Now try estimating the following energy values:

- a) energy to make hot water for one bath
- b) energy per year for one household's hot water in Britain
- c) energy per day for average house's central heating
- d) energy to run an average car 1000 miles

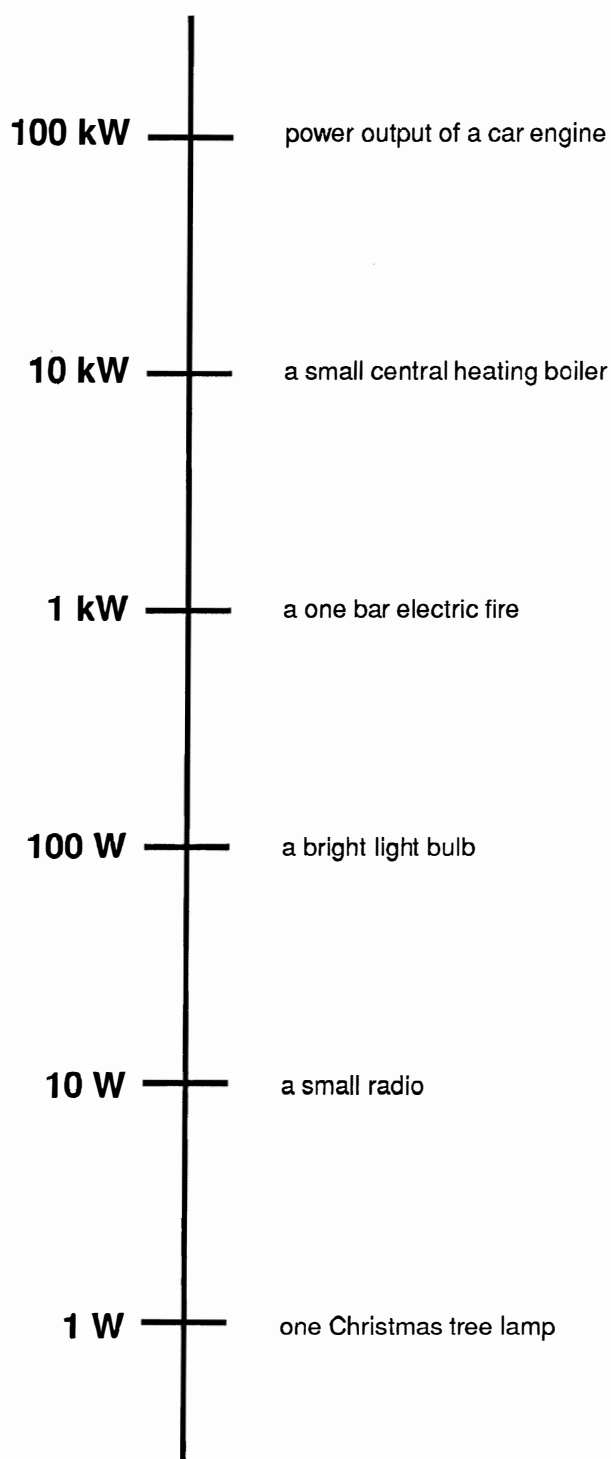
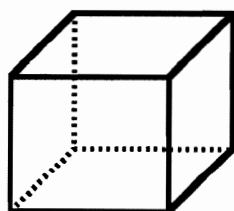
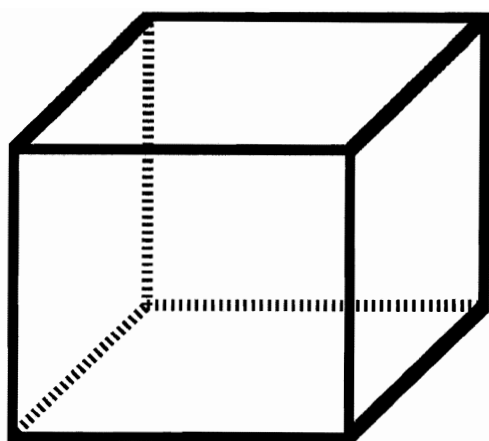
3. Now try estimating the following power values:

- a) power consumption per person in Britain
- b) world average power consumption per person
- c) power consumption per person in USA
- d) power consumption per person in India

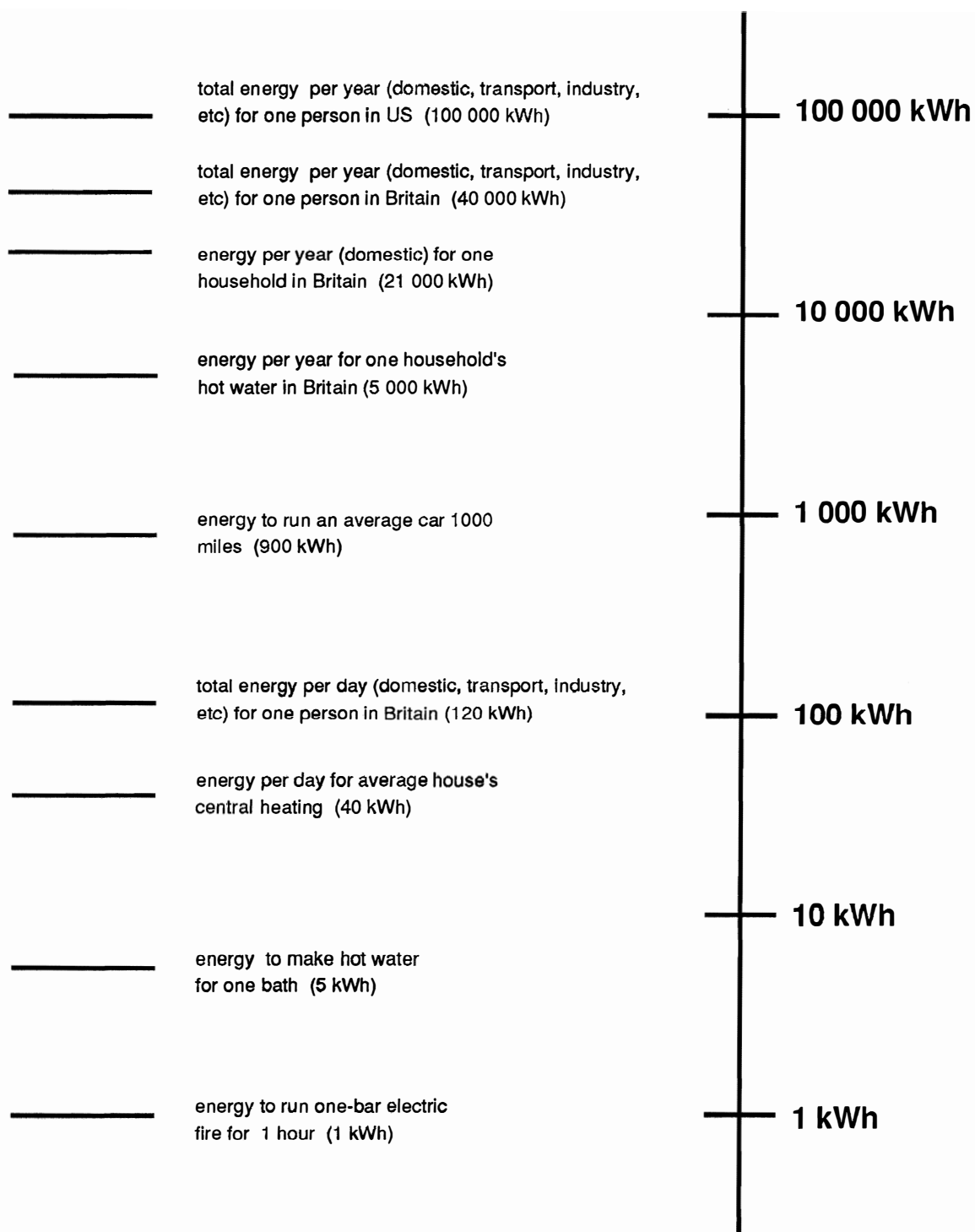
Energy ladder - getting to know the kWh



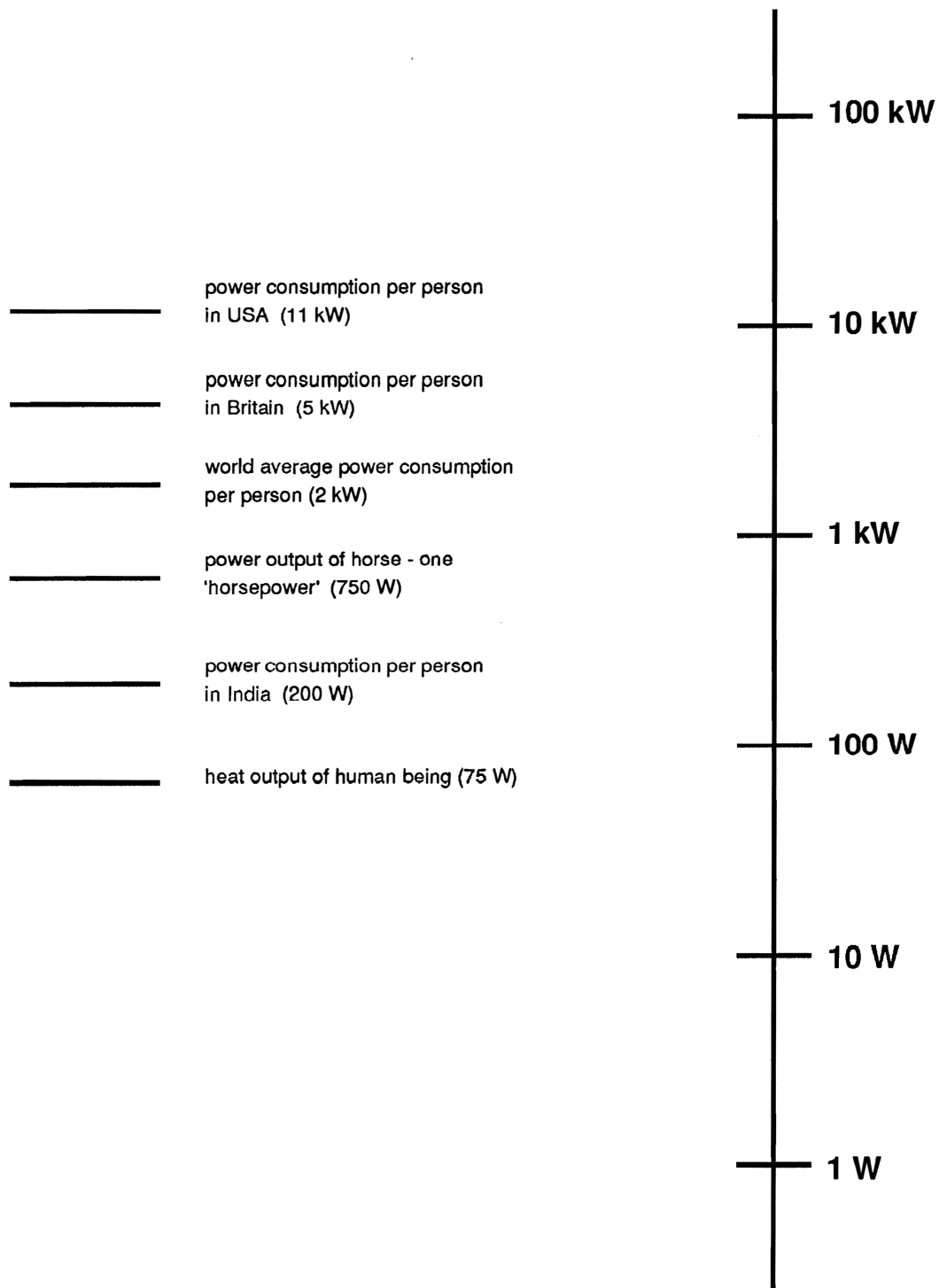
Power ladder - getting to know the kW



Energy ladder - household energies



Power ladder - household powers

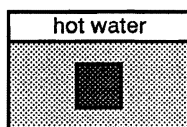
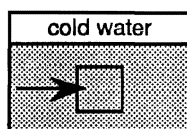


Measuring energy and power

Energy and power

Suppose we are heating up some water in a saucepan. To make it boil we need to add energy to the water.

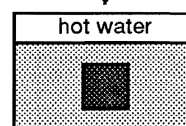
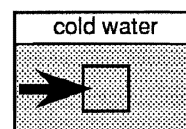
Here, we are adding energy to the water *slowly*, so it takes a *long* time to boil.



We could turn up the cooker, and add energy more *quickly*.

We still need to add the *same amount* of energy, so it takes *less* time to boil.

The rate at which we add energy is called the power.



low power



high power



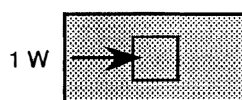
Measuring small amounts of energy

In the laboratory, we usually measure energy in joules (J).

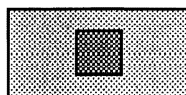
We can measure power in watts (W).

A watt is a rate of flow of energy of 1 joule per second ($1\text{W} = 1\text{J/s}$).

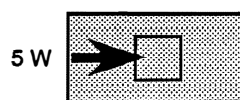
So, if energy flows at the rate of 5W for 4 seconds, a total of 20J of energy has flowed.



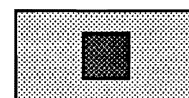
1 second



1 J added



4 seconds



20 J added

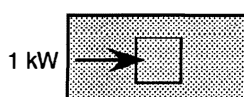
Measuring large amounts of energy

In the home, large amounts of energy are used. For example, an average household in Britain uses about 200 000 000 J per day.

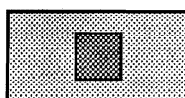
To make the numbers easier to manage, we use different units of energy. On fuel bills, energy is measured in kilowatt-hours, or kWh.

1kWh is the amount of energy which flows with a rate of 1kW for 1 hour.

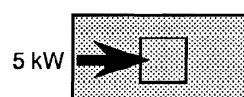
An average household in Britain uses about 60 kWh of energy per day.



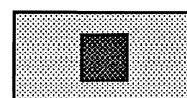
1 hour



1 kWh added



4 hours



20 kWh added

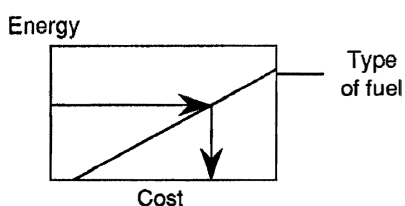
Working out fuel costs

Sheet 1

There are many ways you could boil a litre of water. You could use an electric kettle, you could put it on a gas cooker, you could use a camping stove, you could put it over a wood fire, and so one.

Whichever fuel you use, the *amount of energy* needed to boil a litre of water will be the *same* for all these fuels (assuming that none of the energy escapes). However, the *cost* of these fuels is *different*.

The chart on the following sheet allows you to work out the costs of using fuels. If you know how much energy you need, and the fuel you want to use, you can read off the cost:



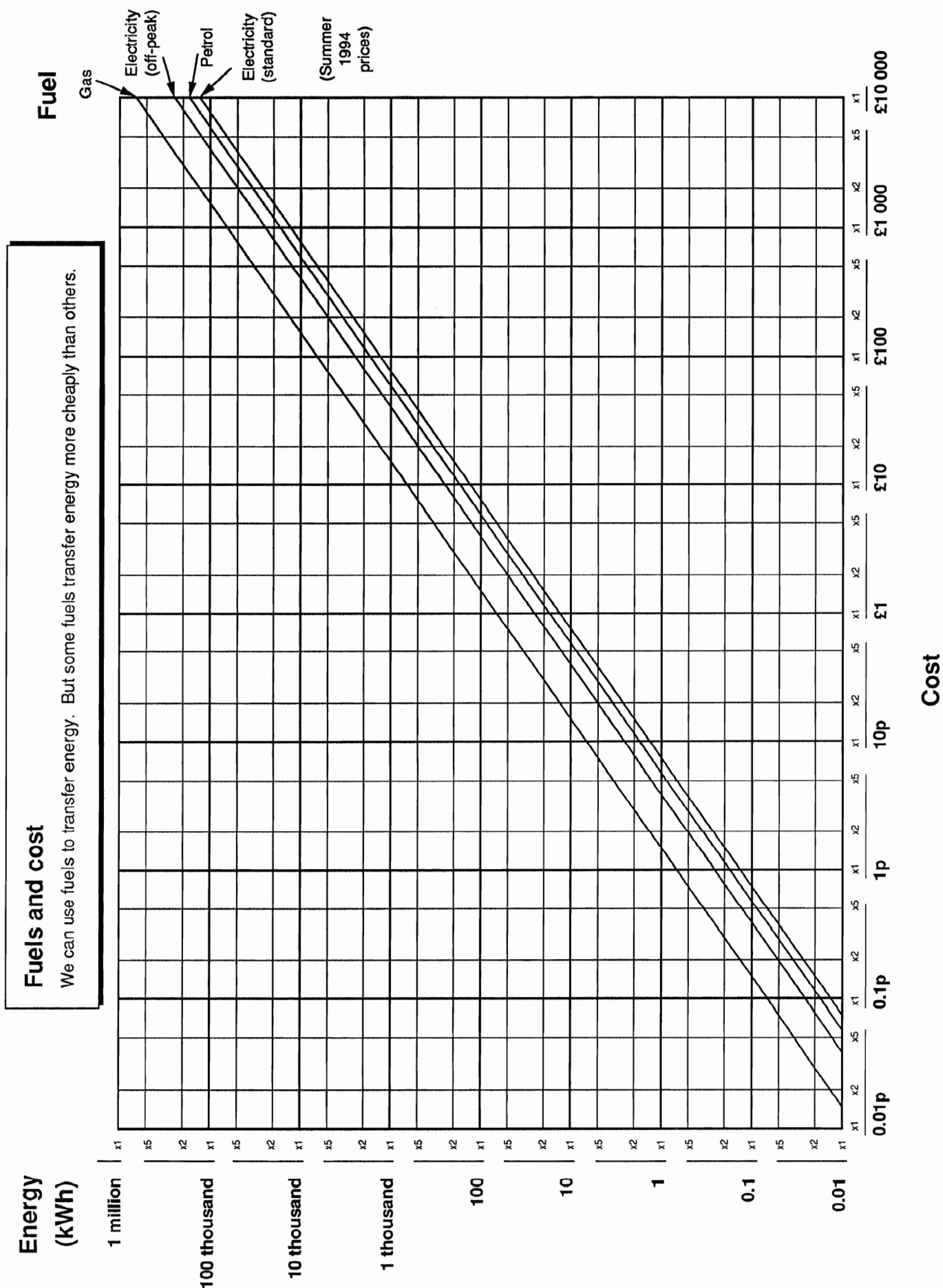
N.B. The graph lets you make *estimates* - you can only read off *approximate* values when you are using the chart.

Questions

1 Without using the chart, can you guess the cost of each of the following:

- a) running a one-bar electric fire for 1 hour (1 kWh)
- b) using gas to make hot water for one bath (5 kWh)
- c) using gas for one year's supply of hot water for a British household (5 000 kWh)
- d) using standard rate electricity for one year's supply of hot water (5 000 kWh)
- e) running an average car on petrol for 1000 miles (900 kWh)
- f) using gas for one day for an average house's central heating (40 kWh)
- g) using off-peak electricity for one day for an average house's central heating (40 kWh)
- h) using gas for the total annual energy needs (domestic, transport, industry, etc) for one person in Britain (40 000 kWh)

2 Now use the chart to estimate the costs.



Hot water in your home

Sheet 1

We use a lot of hot water in the home - for washing dishes, washing our hands, taking baths and showers. This sheet shows you how to work out how much all this hot water costs.

STEP 1 How much water do we use?

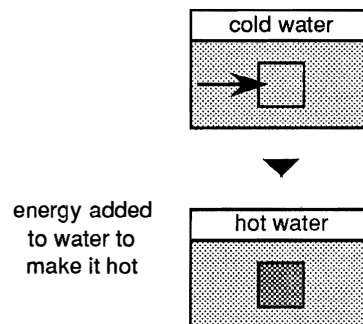
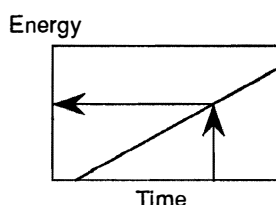
Guess amount of water which is used every day. Use the table shown here.

	Volume used (litres)
Hand basin	5
Washing up bowl	10
Shower	20
Bath	100

STEP 2 Making it hot

We need to put energy into all this water to make it hot.

Work out how much energy is used to heat the water over a whole year. Use Chart 1.



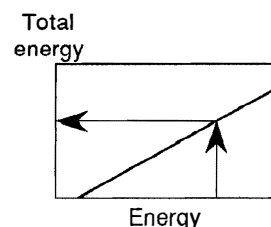
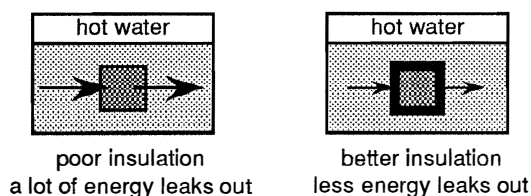
STEP 3 Keeping it hot

Even after we have made the water hot, we still need to keep adding energy.

Most homes have a tank to store the hot water. Because the water is hotter than the air around the tank, energy leaks out the tank. So extra energy must be added to replace this.

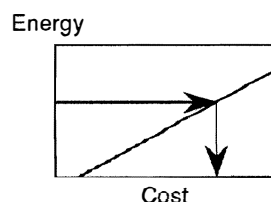
How much energy we need to add depends on how much energy leaks out. This depends on how well insulated the tank is. If it is well-insulated we will need less energy.

Find out how much more energy is used to allow for leakage. You need to decide how good the insulation of the tank is. Use Chart 2.



STEP 4 How much does it cost?

Finally, find out the cost of the energy using the chart from Activity 4 ('Working out fuel costs').



Cost of hot water

You can work out the cost of heating water from:

- how much water is used per day
- how good the insulation of the tank is
- the cost of fuel

The first example has been done for you. Complete the other two.
You are only making estimates - just choose approximate numbers when you are reading from the graphs.

	STEP 1 Amount of water used per day	STEP 2 Energy used in one year to make it hot	STEP 3 Total energy used in one year	STEP 4 Cost
	150 litres	3 thousand kWh	10 thousand kWh	£ 150

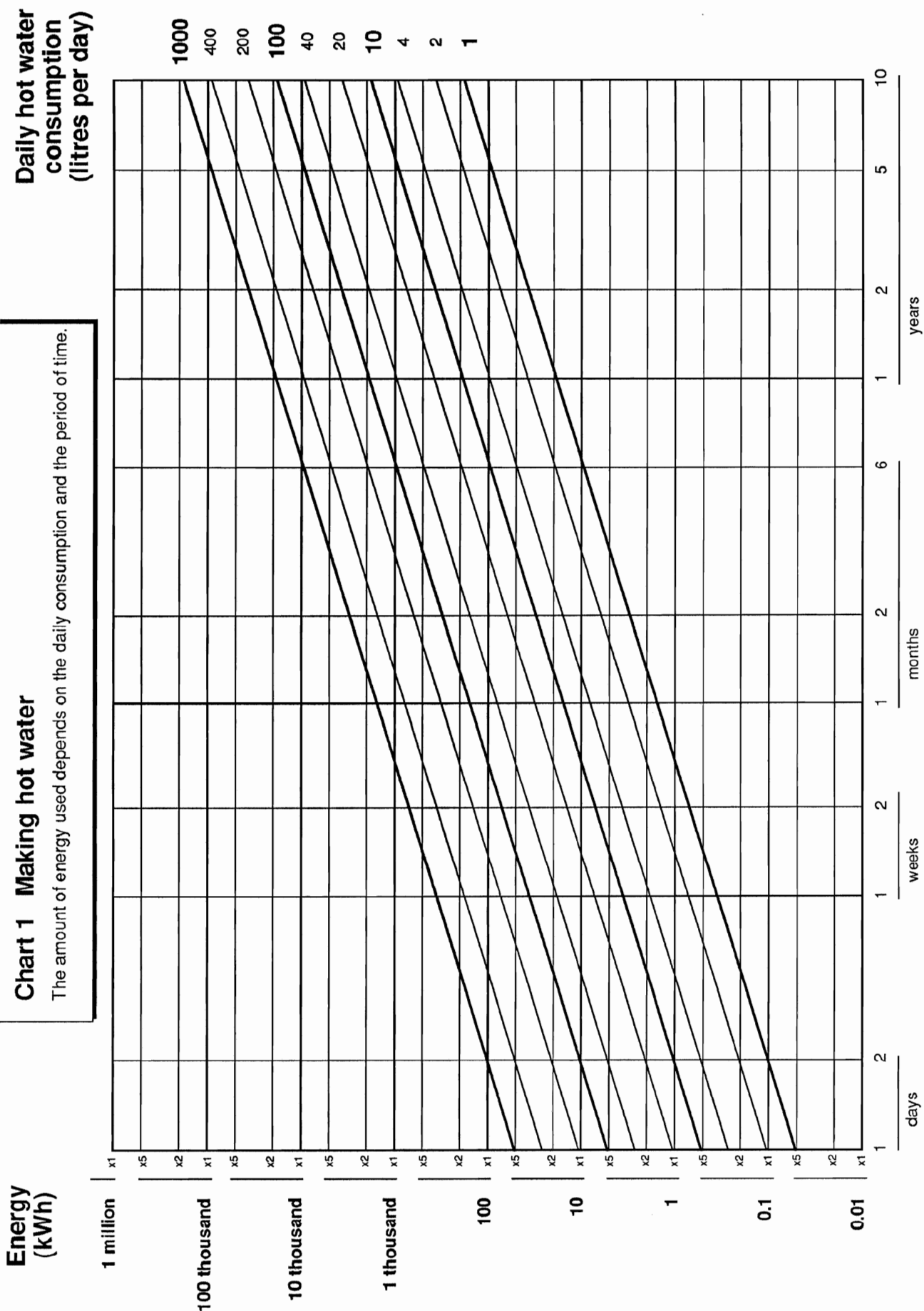
Example 1
A single woman takes one bath every day (100 litres) and uses another 50 litres a day for washing. The tank is poorly insulated. She uses a gas boiler.

Example 2
She tries to economise by using less water. She now uses 100 litres a day. She also adds good insulation to the tank.

Example 3
There are four people living in a house. Each person uses 50 litres of water per day. The tank has average insulation. They use a gas boiler.

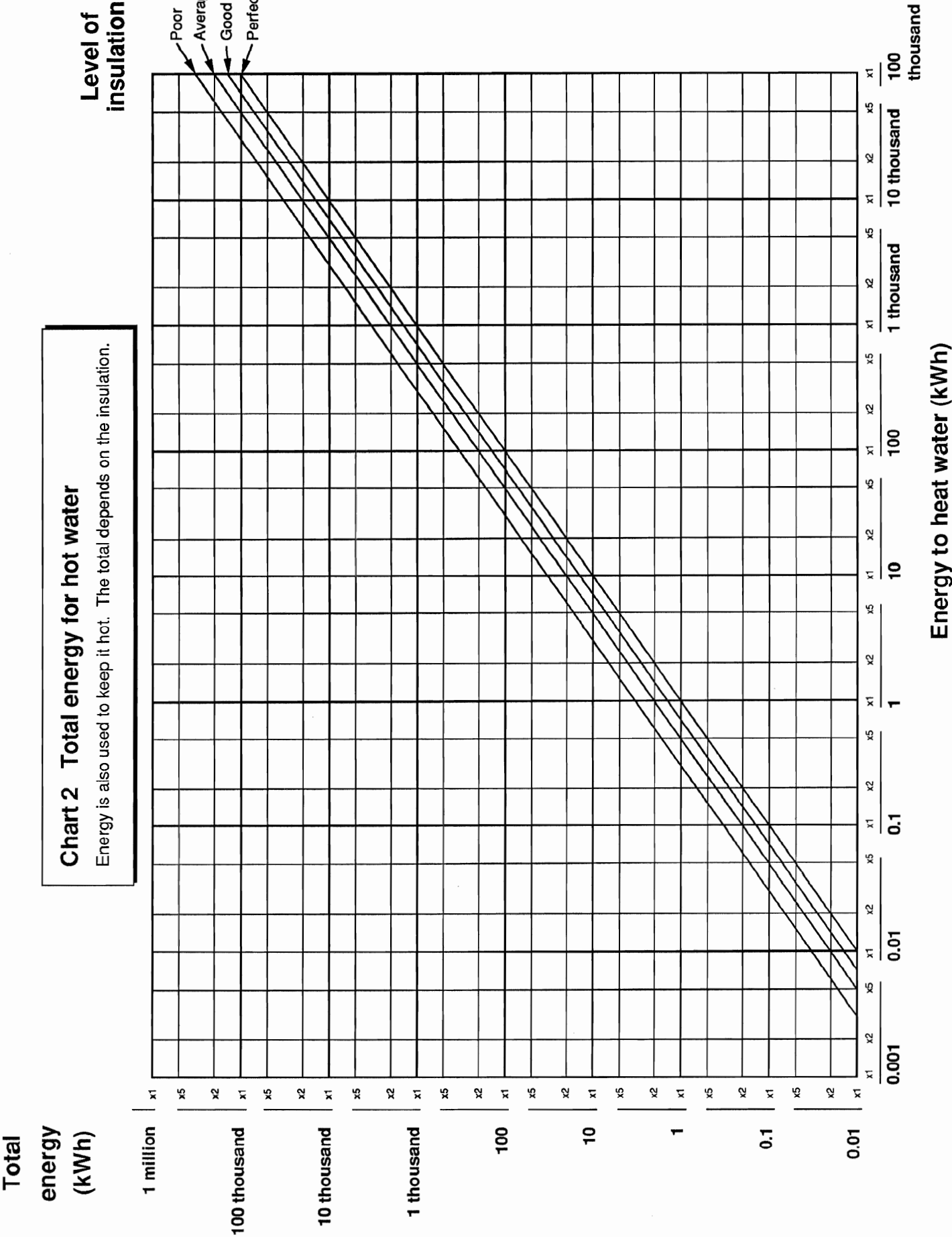
Chart 1 Making hot water

The amount of energy used depends on the daily consumption and the period of time.

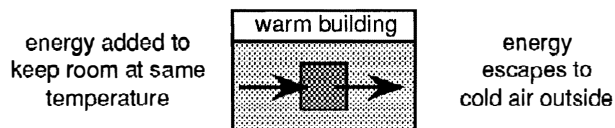


Time used

Water heated from 15 to 60 deg C



Most of the time, we want to keep our homes warmer than the air outside. So, energy escapes from the warm rooms inside to the cold air outside. To keep our homes warm we need to keep adding energy. This sheet shows you how to work out how much it costs to keep a home warm.

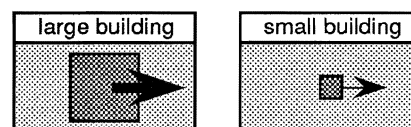


STEP 1 Finding out the 'energy leakage factor'

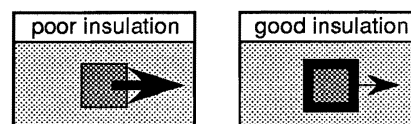
How quickly energy escapes depends on how 'leaky' the building is:

- energy tends to leak faster from big buildings than from small ones
- energy tends to leak faster from poorly insulated buildings

For any building we can work out an 'energy leakage factor' which tells us how quickly the building lets energy escape.



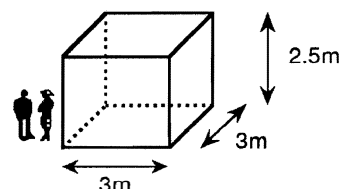
more energy escaping from a big building



more energy escaping from a poorly insulated building

You need to work out how many 'typically-sized' rooms there are.

This is the size of a typical room.



Then you can find out the 'energy leakage factor' which tells you how 'leaky' the building is.

How many ground floor rooms?
How well insulated?

How many top rooms?
How well insulated?

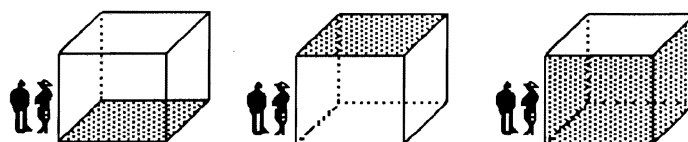
How many external walls?
How well insulated?

a) Do this first for energy leaking through the ground (table 1).

b) Then do the roof (table 2).

c) Then do the walls (table 3).

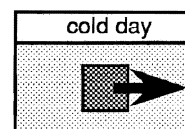
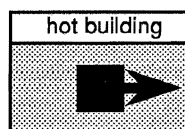
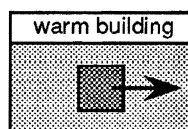
d) Finally, add the three values together, to get the total leakage factor.



add all the factors together

STEP 2 How quickly does energy leak away?

How quickly energy escapes also depends on how hot it is inside and how cold it is outside. Energy will escape faster when the temperature difference is bigger.

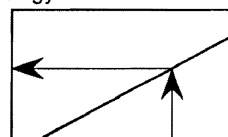


more energy escaping with
bigger temperature differences

Work out how quickly energy leaks from the building, using the leakage factor and the temperature difference (chart 1).

An average temperature difference over a year would be 10 degrees C.

Rate of energy loss



Energy leakage factor

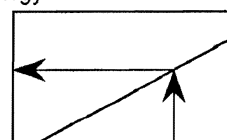
STEP 3 How much energy is added?

We now know how quickly the energy escapes. This tells us how quickly we need to add energy to keep the building at the same temperature.

The total amount of energy depends on the period of time (e.g a day, a year).

Work out how much energy needs to be added over the period of time you want.

Energy

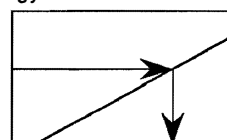


Time

STEP 4 How much does it cost?

Finally, find out the cost of the energy using the chart from Activity 4 ('Working out fuel costs').

Energy



Cost

Cost of heating your home

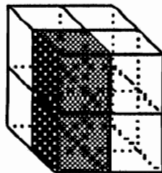
You can work out the cost of heating a flat or a house from:

- how big the building is
- how well-insulated it is
- the temperature of the rooms
- the cost of fuel

The first example has been done for you. Complete the other example. You are only making estimates - just choose approximate numbers when you are reading from the graphs.

Example 1

A small top-floor flat is heated by electricity. It is poorly insulated.



Number of rooms on ground = 0

Number of rooms with roof = 2

Number of outside walls = 4

Average temperature difference over the year = 10 deg C

STEP 1

Energy leakage factors

0
+ 40
+ 90

= 130

STEP 2

Rate of energy leakage

1.5 kW

STEP 3

Energy used in one year

20 thousand kWh

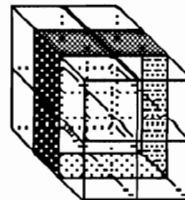
STEP 4

Cost

£ 1,500

Example 2

A small terraced house is heated by gas. It has average insulation.



Number of rooms on ground = 2

Number of rooms with roof = 2

Number of outside walls = 4

Average temperature difference over the year = 10 deg C

Energy leakage factors

Table 1 Through the ground

No. of 'rooms' on ground *	Insulation **		
	Good	Average	Poor
1	10	15	20
2	20	30	40
3	30	45	60
4	40	60	80
5	50	75	100
6	60	90	120

* Count number of 'rooms' at ground level
(of floor size 3m x 3m)

** Decide on level of insulation, e.g.:
Good = concrete floor with cork tiles
Poor = wooden floor with lino

Table 2 Through the roof

No. of 'rooms' with roof *	Insulation **		
	Good	Average	Poor
1	5	15	20
2	10	30	40
3	15	45	60
4	20	60	80
5	25	75	100
6	30	90	120

* Count number of 'rooms' with roof
(of ceiling size 3m x 3m)

** Decide on level of insulation, e.g.:
Good = tiled roof with thick loft insulation
Poor = tiled roof with no insulation

Table 3 Through the walls and windows

No. of walls' *	Insulation **		
	Good	Average	Poor
1	10	15	25
2	15	30	45
3	25	45	70
4	30	60	90
5	40	75	115
6	45	90	135
7	55	105	160
8	60	120	180
9	70	135	205
10	75	150	225
12	90	180	270
15	115	225	340
20	150	300	450

* Count number of 'outside walls'
(of size 3m x 2.5m with window 1.5m x 1m)

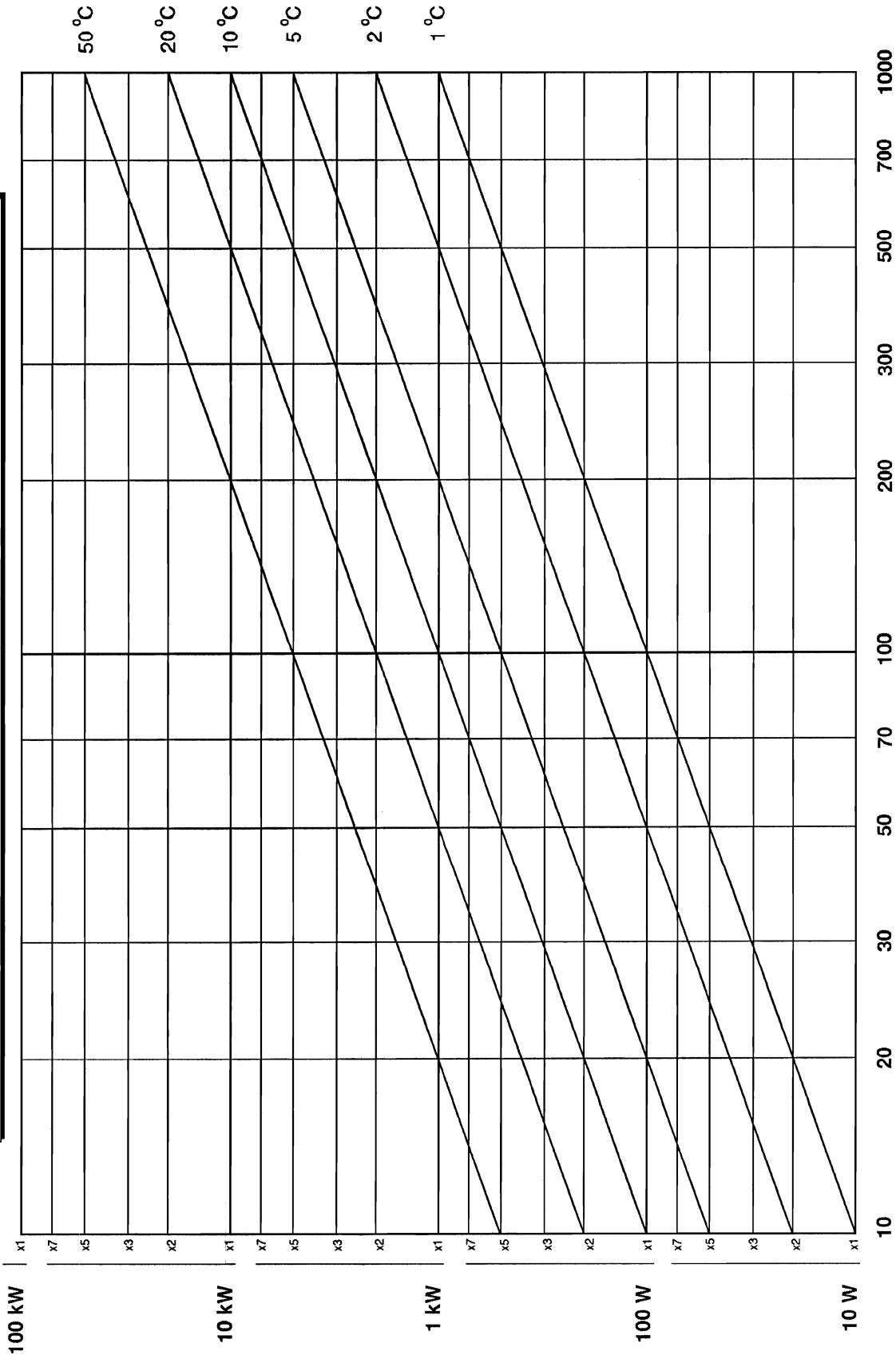
** Decide on level of insulation, e.g.:
Good = thick wall with foam infill and
double glazed windows
Poor = thin wall with single glazed windows

N.B. Energy leakage factors are measured in $W / ^\circ C$. They are commonly called U values.

Rate of energy leakage

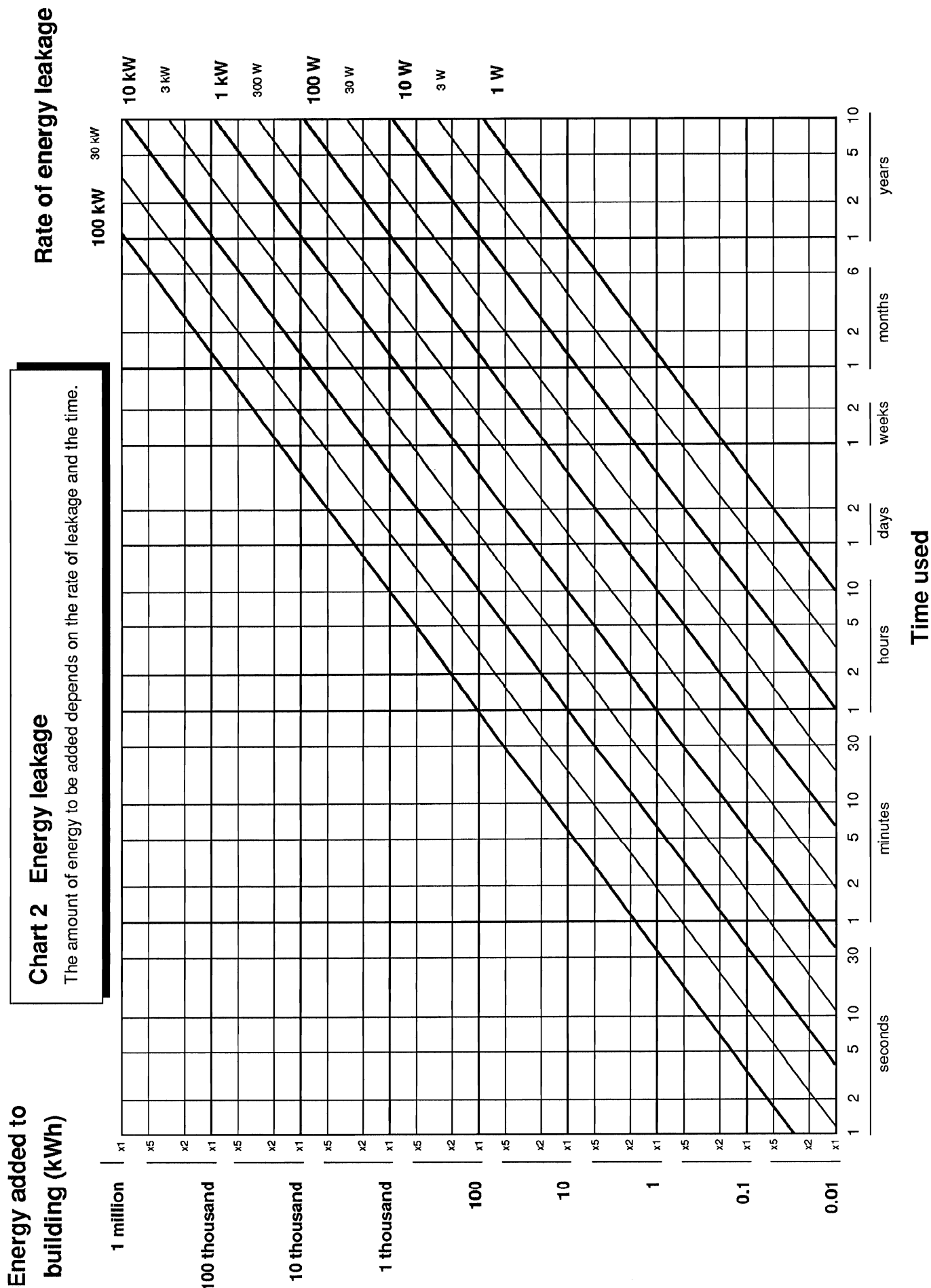
Chart 1 Rate of energy leakage
The rate at which energy escapes depends on the energy leakage factor and the temperature difference.

Temperature difference



Energy leakage factor

(NB Energy leakage factor in W per deg C)



Electricity carries energy from the power station into our homes. There are many different kinds of electrical appliances - some of these use electricity to make things hot (e.g. a kettle, a light bulb) and others use electricity to make things move (e.g. a food mixer, an electric drill). This sheet shows you how to work out how much it costs to keep electricity flowing.

STEP 1 Finding the power rating

The power rating of an electrical appliance is the rate at which energy flows through it. It is measured in W (or kW).

For example, energy flows at a bigger rate through an electric drill, so it has a bigger power rating than a light bulb.

Find the power rating of the appliance (tables 1-3).

light bulb

low power

electric drill

high power

STEP 2 How often is it used?

However, light bulbs are usually used more often than electric drills. Over a whole year, much more energy could flow through the light bulb, and could cost much more to run.

Guess how long it is used in one day. Then, find out how long this would be for the whole year (table 4).

light bulb

long time

electric drill

short time

light bulb

a lot of energy

electric drill

not so much energy

STEP 3 How much energy?

From the power rating and the time used, find the amount of energy used from the chart.

Energy

Time

STEP 4 How much does it cost?

Finally, find out the cost of the energy using the chart from Activity 4 ('Working out fuel costs').

Energy

Cost

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Energy and change

Sheet I7/1

Cost of using electrical appliances

You can work out the cost of using an electrical appliance from:

- its power rating
- the length of time you use it
- the cost of electricity

Complete the examples in the table below. The first two have been done for you. Add some examples of your own. You are only making estimates - just choose approximate numbers when you are reading from the graphs.

Appliance	STEP 1 Power ratings	STEP 2 Guess the daily use	STEP 2 (cont.) How long they are used over a year	STEP 3 Energy used	STEP 4 Cost
electric kettle	2 kW	10 min	2 days	150 kWh	£ 10
stereo system	75 W	2 hours	1 month	50 kWh	£ 4
vacuum cleaner		10 min			
chip fryer		5 min			
fridge freezer					
colour TV					

Table 1 Power ratings of electrical appliances

Appliance	Power (typical values)	
washing machine	3000 W	3 kW
electric kettle	2000 W	2 kW
iron	2000 W	2 kW
chip fryer	1500 W	1.5 kW
vacuum cleaner	1200 W	1.2 kW
spin drier	600 W	
electric toaster	500 W	
electric drill	500 W	
fridge freezer	150 W	
large colour TV	100 W	
stereo system	75 W	
car battery charger	50 W	
small black and white TV	30 W	
video recorder	25 W	
radio	20 W	

Table 2 Power ratings of some light bulbs

Bulb	Power
Main light for room	100 W
For desk lamp	60 W
For bedside light	40 W

Table 3 Power ratings of electrical heating appliances

Appliance	Power (typical values)	
<i>Cooking</i>		
electric cooker (total)	12000 W	12 kW
<i>Hot water</i>		
immersion heater	3000 W	3 kW
<i>Space heating</i>		
fan heater	3000 W	3 kW
electric fire (2 bar)	2000 W	2 kW

Table 4 Yearly use of appliances

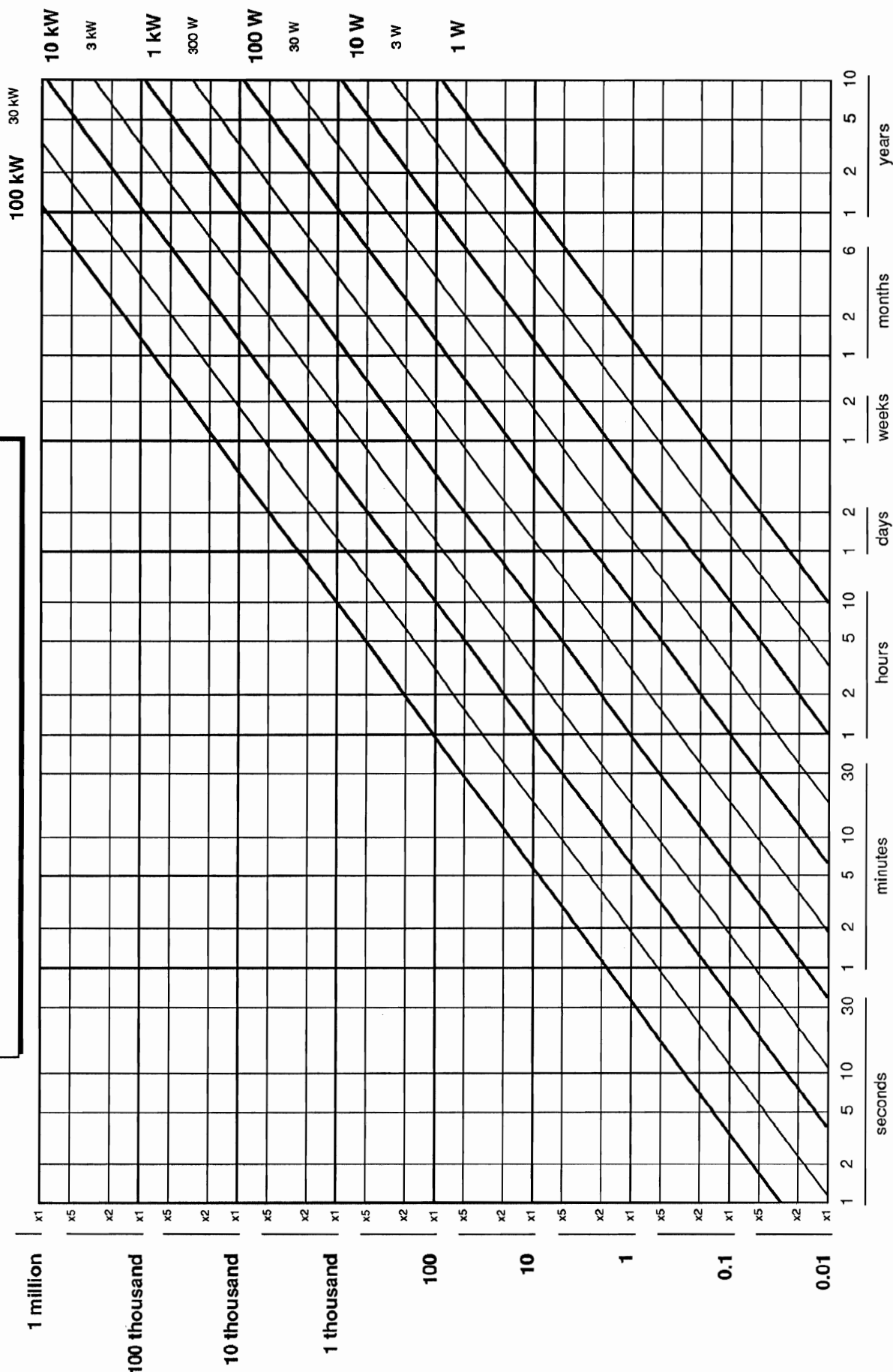
If an appliance is used this much in <i>one day ...</i>	... it adds up to this much in <i>one year</i>
1 minute	5 hours
5 minutes	1 day
10 minutes	2 days
30 minutes	1 week
1 hour	2 weeks
2 hours	1 month
4 hours	2 months
12 hours	6 months
24 hours	1 year

**Energy
(kWh)**

Electrical appliances

The amount of energy depends on its power rating and the time used.

Power ratings

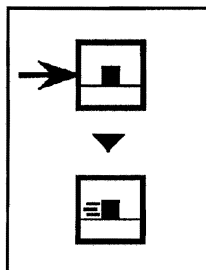


Imagine you are going for a drive in a car. How much will it cost? This sheet shows you how to do this for a very simple journey - the car accelerates, and then stays at a steady speed for the whole journey. Fuel needs to be burnt to get the car moving and then to keep it moving at a steady speed.

STEP 1 Getting it moving

We need energy to get the car moving. The faster we want the car to move, the more energy we need to put in.

Work out the energy needed for a typical car from the table.



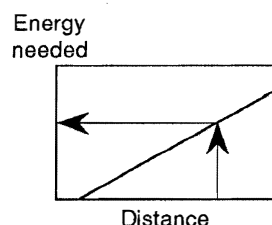
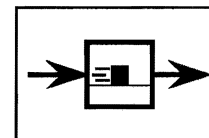
Speed (mph)	Energy used (kWh)
10	0.003
30	0.02
50	0.07
70	0.13
90	0.22

STEP 2 Keeping it moving

If there was no friction, the car would keep going at the same speed with no further energy input. But energy escapes from the moving car - warming up the tyres, the road, the air, and so on. So we need to keep putting energy in to keep the car moving.

The energy needed depends on the distance you travel. It also depends on the speed - you need to put in more energy to keep it moving at a higher speed.

Work out the energy needed to keep a typical car going from Chart 1.

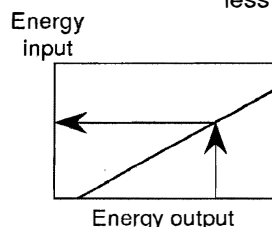
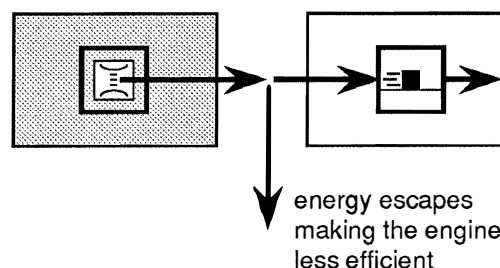


STEP 3 Engine efficiency

Most of the energy released from burning petrol in a car engine is not transferred to the wheels - instead it simply makes the engine hot. Because so much energy escapes, the car engine is not very efficient - at best, only about 25%. This means that the energy output of the engine is 25% of the energy input.

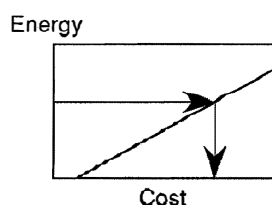
The efficiency of the car engine depends on the speed - it is much less efficient when it runs slower.

Find the energy input needed to produce the required energy output. Use Chart 2.



STEP 4 How much does it cost?

Finally, find out the cost of the energy using the chart from Activity 4 ('Working out fuel costs').



Cost of running a car

You can work out the cost of fuel for a car from:

- the distance travelled
- the speed
- the cost of petrol

The first example has been done for you. Complete the other two.
You are only making estimates - just choose approximate numbers when you are reading from the graphs.

	STEP 1 Energy needed to get car moving	STEP 2 Energy needed to get car moving	STEP 2 (cont.) Total energy output needed	STEP 3 Energy input to engine	STEP 4 Cost		
Example 1 A car starts off and travels at 30 mph for 1 mile.	Speed of car 30 mph	Distance travelled 10 miles	0.02 kWh	0.1 kWh	0.12 kWh	1 kWh	£ 0.06
Example 2 A car starts off and travels at 10 mph for 100 miles.							
Example 3 A car starts off and travels at 50 mph for 100 miles.							

