Your Stars - Revelation or Reassurance

Contents: A practical investigation of the validity of astrology.

Time: 2 periods.

Intended use: As part of any GCSE Science course which includes a consideration of the methods and processes of science.

Aims:

- To provide an opportunity to evaluate the reliability of predictions
- To show that it can be difficult to test predictions because of chance variation in the observations
- To develop awareness of the way in which statistical methods are used to evaluate the significance of experimental results
- To develop awareness of the difficulty of setting up an objective test in a context which involves beliefs and personal feelings
- To provide an opportunity to discuss the differences between science and pseudo-science.

Requirements: Students' worksheets No.907. Coins or computers for Part 2. An adapted horoscope from a recently published magazine for Part 3.

Authors: Alan Attwood and Andrew Hunt

Introduction

A lively account of the life and work of Johannes Kepler is given in *The Sleepwalkers* by Arthur Koestler (Penguin Books, 1986). Kepler began his career publishing astrological calendars and ended it as Court Astrologer to the Duke of Wallenstein. Koestler points out that Kepler rejected the then current practices of astrologers as quackery; but Kepler believed that there could be a new and true astrology.

Another source of information about Kepler is the chapter about him in the book *Cosmos* by Carl Sagan (Futura, 1983). While this does not explicitly discuss Kepler's astrological work, it does make the point that he badly wanted to believe in astrology (and other 'mystic' concepts), but that he ultimately put his scientific principles before his cherished beliefs. The chapter also highlights how the technique for predicting planetary positions, followed by an evaluation of the predictions, played a fundamental part in the formulation of Kepler's famous laws of planetary motion.

Popular astrology remains faithful to tradition and ignores the precession of the equinoxes. Astrologers use the vernal equinox as their reference point. The equinox moves eastward 1.4 degrees each century through the 'fixed' stars and a shift of 30 degrees has occurred in the past 2000 years. Zodiacal signs refer to 30-degree sectors of the ecliptic and not to constellations. Thus the traditional astrologers' sign of Aries coincides roughly with the real constellation of Pisces. However, there are sidereal astrologers who do take note of the movement of the Earth's axis relative to the stars and assign different dates to the birth signs.

Part 2 Testing predictions

The derivation of the 40 to 60 range quoted in the unit is given below. This information is included as background for teachers and it is not intended for the students.

Coin tossing is described by the binomial distribution. It is conventional to use the 5 per cent probability level when tests of significance are carried out. The 5 per cent level means that extreme results with only a 5 per cent chance of occurring are taken as evidence that the hypothesis under consideration is false.

In the example of tossing a coin 100 times, one can calculate the range within which 95 per cent of the results are expected to fall by the following (approximate) method:

Calculate the standard deviation, σ, of the binomial distribution. If p is the probability of success and q the probability of failure, then for n trials:

$$\sigma = \sqrt{npq}$$

For coin tossing $p = q = \frac{1}{2}$, so for one hundred tosses:

$$\sigma = \sqrt{100 \times \frac{1}{2} \times \frac{1}{2}} = 5$$

The mean = (number of trials) × (probability of success) = $100 \times \frac{1}{2} = 50$

Now take $\pm\, 2\sigma$ from the mean as the 95 per cent range.

(The value 2 comes from the normal distribution and it is an approximation to apply it here.)

So for a hundred tosses there is a 95 per cent chance that the number of heads will lie between 40 and 60. (A more accurate calculation shows that the probability is 96 per cent.)

If a result is obtained which lies outside the 95 per cent range, it could have occurred by chance on only 5 per cent of the occasions on which the exercise is repeated. If this happens it is usual to conclude that the coin is biased or the method of tossing is biased. In drawing this conclusion one has a 5 per cent chance of being wrong.

A similar argument applies to the numbers of odds and evens in a list of randomly generated numbers. It is a more realistic exercise to check for bias in a calculator than in a coin. Some students might be interested to explore the effect of weighting a coin on one side — perhaps with Plasticine or Blu-tack.

Part 3 Your stars

Before starting Part 3 it might be a good idea to ask the students to suggest how they would plan to measure the reliability of horoscope predictions. Students may suggest keeping a note of the predictions over a week or so and then rating them for accuracy at the end of the period. This provides an opportunity to discuss the difficulty of deciding objectively whether or not a vaguely worded prediction has proved correct.

Requirements

For this part the teacher will need a horoscope from a recent newspaper or magazine — preferably a magazine published for younger readers. The horoscopes in weekly magazines are generally more detailed. Cut up the statements, re-order them and number them. Make copies for the students.

There is always a risk that one or two students may, by chance, have already seen the magazine chosen by the teacher and read their horoscope in it. They are unlikely to have read all the other eleven horoscopes, so the probability is high that they will remember which is 'theirs'. This could distort the results significantly with a small sample. The risk can be minimized: (a) by picking a magazine which has just been published and using it on the day of publication; and (b) by appealing to the students' honesty and asking them to withdraw from the exercise if they have seen the magazine in question.

The following examples show how to determine whether the results have any statistical significance for the size of sample involved. As in Part 2, it is not suggested that students should be shown the details of the statistics.

In this case there is a 1 in 12 chance of a student picking the correct statement.

$p = \frac{1}{12}$ and $q = \frac{11}{12}$.

For a class of 30 students

$\sigma = \sqrt{30 \times \frac{1}{12} \times \frac{11}{12}} \approx 1.5$

The mean $= 30 \times \frac{1}{12} \approx 3$

Rounded to whole numbers the 95 per cent range is about 3 ± 3

So the result will be significant at the 5 per cent level if more than 6 students pick the correct statement for their birth sign.

For one hundred students

$\sigma = \sqrt{100 \times \frac{1}{12} \times \frac{11}{12}} \approx 3$

The mean $= 100 \times \frac{1}{12} \approx 8$

Rounded to whole numbers the 95 per cent range is about 8 ± 6. Any result in this range could happen purely by chance.

So the result will be significant at the 5 per cent level if more than 14 students pick the correct statement for their birth sign, in which case we might conclude that there is some validity in these predictions.

Part 4 You and your birth sign

The same statistics apply as in Part 3. The sample size could be increased if students take away a copy of the statements and ask other students in the school to take part in the exercise. The teacher will then have to help to collate and interpret the results as in Part 3.

The statements and signs are related as follows:

A Virgo
B Pisces
C Libra
D Capricorn
E Scorpio
F Gemini
G Cancer
H Aquarius
I Leo
J Aries
K Taurus
L Sagittarius

These statements are based on a set used in a study reported in the US in the 22 January, 1980 edition of the *National Enquirer.* That study claimed that an amazing 91 per cent of 240 randomly selected people picked the correct statement. A report in the *Skeptical Inquirer* (Winter 1980-81), describes a study which attempted to replicate the earlier work. The second investigation found that only 26 out of 262 students chose the correct statement. This is in the range expected by chance.

Further resources

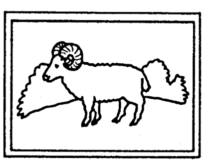
Another way of testing astrological predictions is given on pages 164-5 of Nuffield Science 11-13, *Pupils' Book I, How Scientists Work* (Longman, Harlow, 1986). The approach is discussed on pages 165-6 of the corresponding *Teachers Guide I.*

YOUR STARS — REVELATION OR REASSURANCE?

Astrologers believe that a person's character is determined by the position of the sun, the moon, the planets and the stars at the moment of birth.

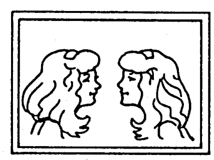
Astrologers also try to predict what is going to happen. Have you ever studied 'Your Stars' in a newspaper? If so you have been trying to find out about your future. You have been looking for help with *predicting* what will happen to you in the days or weeks ahead.

The predictions of astrologers are linked to the signs of the zodiac. The zodiac is the part of the sky where we see the sun, the moon and the planets against the background of the stars. The groups of stars in the zodiac have names and symbols, as shown in Figure 1. Everyone is born under a particular sign of the zodiac. This is the group of stars in which the sun appeared when you were born.

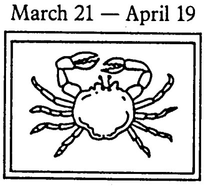


Aries the ram
March 21 — April 19

Taurus the bull
April 20 — May 20



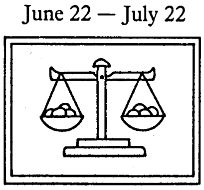
Gemini the twins
May 21 — June 21



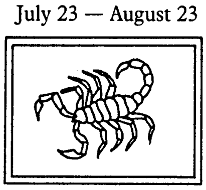
Cancer the crab
June 22 — July 22

Leo the lion
July 23 — August 23

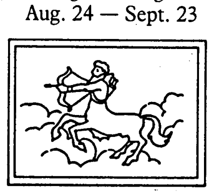
Virgo the virgin
Aug. 24 — Sept. 23



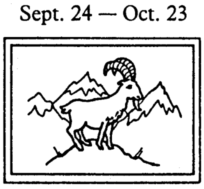
Libra the scales
Sept. 24 — Oct. 23



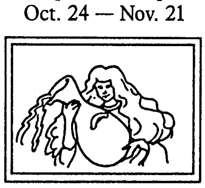
Scorpio the scorpion
Oct. 24 — Nov. 21



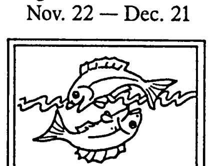
Sagittarius the archer
Nov. 22 — Dec. 21



Capricorn the goat
Dec. 22 — Jan. 19



Aquarius the water carrier
Jan. 20 — Feb. 18



Pisces the fish
Feb. 19 — March 20

Figure 1 The signs of the zodiac

Now answer questions 1 and 2.

This unit is in four parts:
Part 1 is about the way scientists make predictions
Part 2 shows that it can be difficult to test predictions
Part 3 asks you to investigate whether there is any value in the predictions made by astrologers
Part 4 asks you to test whether there is any connection between someone's birth sign and their character.

Johannes Kepler

We now remember Johannes Kepler as a famous astronomer. His first job was at Gratz in Austria where he was a teacher of astronomy and mathematics. Part of his job was to publish an annual calendar of astrological forecasts.

Kepler cast his own horoscope and wrote:

> 'Johannes Kepler, Keppler, Khepler, Kheppler, Keplerus was conceived on 16 May A.D. 1571, at 4.37 a.m., and was born on 27 December at 2.30 p.m., after a pregnancy lasting 224 days, 9 hours and 53 minutes.'

Kepler was vague about the spelling of his name but very precise about the moment of his birth.

Questions

1. *What is the difference between astrology and astronomy?*
2. *Do you think that there are now official mathematicians and astronomers who earn money by casting horoscopes?*

Part 1 Making predictions

Scientists are in the business of trying to work out what will happen in the future. They use their observations and theories to make predictions. For example, the weather forecasts on TV are made by scientists called meteorologists.

Scientists make predictions to test their theories. If you have studied chemistry you may know that in 1869 a Russian chemist called Dmitri Mendeleév suggested that there were still some elements to be discovered. He predicted their properties. He based his predictions on his new Periodic Table. In a few years the missing elements were discovered. Mendeleév's predictions were found to be correct.

Some theories are more definite than others. They can be used to make more accurate predictions. Here is a list of ten more examples of predictions.

A Meteorologists predict what the weather will be tomorrow.
B Astronomers predict where to look for planets in the night sky for years ahead.
C Risk analysts predict the number of cancer deaths caused by cigarette smoking.
D Gamblers predict the scoring draws for the football matches on a Saturday afternoon.
E Physicists predict the size of the electric current which will flow in a circuit when the switch is closed.
F Environmental scientists predict how burning fossil fuels will affect the climate.
G Doctors predict how long it will take for a broken bone to heal.
H Forensic scientists predict the age, sex and size of a criminal from observations made at the scene of the crime.
I Chemists predict the amount of metal which can be extracted from an ore.
J British Rail timetables predict when InterCity trains will arrive.

Now answer questions 3 and 4.

Questions

3 *Look at the ten examples of scientific predictions A to J listed on this page. List the predictions in order of the accuracy you expect them to have. Put the letter of the most accurate prediction first, and the least accurate prediction last. Compare your order with the order of other people in your group and discuss the differences.*

4 *Now see if you can think of some more examples of predictions. Add your examples to your list from question 3.*

Part 2 Testing predictions

Testing predictions is not as easy as you might expect. Think about spinning a coin. You expect that there is a 50-50 chance that it will come down 'heads'. Suppose you spin a coin ten times and you get 'heads' six times and 'tails' four times. Does that make you change your mind about the chances? What if you spin the coin a hundred times and get 'heads' 47 times? What will happen if you toss it a thousand times?

- When you toss a coin you expect some variation from the 50-50 rules just by chance.
- The more times you toss a coin the closer you are likely to get to 50 per cent 'heads' and 50 per cent 'tails'.

The methods of statistics are used to decide whether something is likely to happen just by chance. Statistics suggest that there is a 96 per cent chance that if you spin a coin a hundred times you will find that the number of 'heads' is between 40 and 60. There is only a 4 per cent chance that you will get less than 40, or more than 60 heads. This is so unlikely that if the number of heads is outside this range you may conclude that you have a biased coin. In making this conclusion you have a 4 per cent chance of being wrong.

Now try activity A or B.

Activity A

Spin a coin ten times. Record the number of times it comes down 'heads'. Now spin it another ten times and record the number of heads. Keep doing this until you have spun the coin a total of one hundred times. How many 'heads' do you get in each lot of ten spins? How many heads do you get for all one hundred spins? What do you find if you add all the results from the whole class?

Activity B

Use a computer to generate a series of random numbers. Produce a list of one hundred numbers. Count the number of even numbers. How many even numbers would you expect? What is the chance variation likely to be? Is your computer biased or not?

Part 3 Your stars

The predictions made by astrologers are called **horoscopes.** You and your class are going to test the predictions made in a magazine or newspaper horoscope. If possible you will use a horoscope aimed at people of your age.

Most horoscopes in the papers make predictions about just a few types of daily or weekly events. They are about such things as friends, family life, work, money and travel.

Your teacher will have chosen a horoscope for a recent day or week. You will be shown twelve predictions — one for each sign of the zodiac. The predictions are numbered but you do not know which goes with which sign. Read them carefully and pick the one which best describes what happened to you during the chosen day or week.

Write down your birth sign and the number of the prediction which you have chosen.

Your teacher will collect the results from the whole class and together you will check the accuracy of the horoscope.

A sample of 20 to 30 from a class is rather small. If each member of the class asks other students to make the same choice you may be able to get a sample of 100 to 200 choices. This will be a better test.

Now answer questions 5 to 8.

Questions

5 *Why choose to test a horoscope designed for people of your age? Do you think that newspaper horoscopes are prepared for young people?*

6 *How easy is it to pick the horosocope which describes what has happened to you? Do you think that astrologers choose their words carefully?*

7 *Do you agree with this statement: 'The astrological predictions in newspapers are worded so generally and vaguely that they could apply to anyone. This is why people think they work.'*

8 *Do you think that this has been a fair test of horoscopes? How might you improve the testing?*

More questions for discussion

9 *Do you think that horoscopes work better for people who believe in them?*

10 *Some people think that newspapers should print a warning above their horoscopes. The warning might say: 'The following astrological forecasts should be read for entertainment value only. Such predictions have no reliable basis in scientific fact.' Do you agree with this idea?*

11 *Can you think of scientific reasons why your character might be affected by your birth sign?*

12 *Apart from your birth sign, what other factors might affect your character? Suggest five or more factors and put them in order. Put the most important one first.*

Part 4 You and your birth sign

Does your birth sign really affect your personality? Look at the list of statements below and pick the one which best describes you. There is one statement for each birth sign — twelve statements altogether.

A I am a perfectionist. I pay attention to small, important details that others often forget. I hate to let a job go until it is finished properly. Others may find me critical but I am more critical of myself than of them.

B I am an 'easy touch'. I would rather help people than make a lot of money. I enjoy day dreaming. I usually get good results by trusting my feelings and following my hunches.

C I am very interested in all of the creative arts, such as writing, art and music. I like to settle arguments between my friends. I'm good at this because I can see both sides of an issue.

D I am very good at making money. I like taking charge and being a leader. I have my sensitive, emotional side, but I show this only to those closest to me. In public, I prefer to remain cool and collected at all times.

E I like to finish whatever I start. My strong determined personality makes me succeed. I can be jealous. I am very passionate.

F I like to create with words either in writing or in speech. I may sometimes dominate conversations. My friends find me witty and interesting, though not always loyal. I am usually logical and cool but change moods quickly and often.

G Family is important to me and I will want to have children. I feel happiest when at home with my family, and pets. I like to spend time helping about the home and cooking.

H My mind is filled with new ideas and I like to invent things. I like to feel that I am in control of my life. I like to be organized and efficient. I like to learn and I have a good memory for facts.

I I am very happy and cheerful. I like making others happy. I am openly emotional and usually optimistic. I like to be looked after and cared for; but I am generous in return.

J I am so enthusiastic about life that I am active at something all the time. I usually have five things going at once. I will work long hours on a project if it interests me. I love to talk and talk quickly. I sometimes exaggerate.

K Once I make up my mind, I don't like to change it. I can be stubborn, especially when I know I'm right. I am too easy going and quiet to get into arguments over anything.

L My love of the outdoors and sports shows me to be a person who hates being tied down in any way. Freedom is what I need. I love animals, travel and humour.

Write down your birth sign and the letter of the statement which you have chosen.

Now answer question 13.

Question

13 Suppose that a hundred students pick a statement. How many would you expect to choose correctly the statement for their sign just by chance?

Why not Combined Heat and Power?

Contents: Reading, questions and data analysis concerning the use of hot water and steam from power stations to run industrial processes and to heat homes.

Time: 2 periods.

Intended use: GCSE Physics and Science courses.

Aims:

- To complement work on energy, power and efficiency
- To show that economics can determine whether or not a particular technology is adopted
- To provide opportunities to practise skills of handling and interpreting data.

Requirements: Students' worksheets No.908.

Authors: Brian Count and Andrew Hunt

The unit is in four parts:

Part 1 Power and efficiency
Part 2 What is combined heat and power?
Part 3 What is district heating?
Part 4 Is CHP with district heating economic?

Parts 1 and 2 can be used on their own; they show that CHP is attractive to industry given suitable economic circumstances.

Parts 3 and 4 show that CHP linked to district heating is only likely to be economically viable in special cases. These parts are designed for more able students.

This unit might be used in conjunction with SATIS unit 308, *The Second Law of— What?*

Notes on some of the questions

The Hereford CHP scheme illustrated in Figure 3 uses diesel engines and waste heat boilers to supply steam and water to two nearby factories and to the local council.

Q.2 34%
Q.3 (a) 19%
Q.4 58%
Q.5 77%

Note that the energy for heating is not 'free' because a CHP station has to burn more fuel to generate the same amount of electricity. The energy for heating has a cost made up of the extra capital cost of the CHP station, plus the cost of the fuel, less the value of the electricity generated. Nevertheless CHP stations can have a big advantage because, if used on a large scale, they can convert about three-quarters of the energy from the fuel into electricity and high-grade heat.

Q.7 CHP schemes are designed to meet the basic heating load. A cheap boiler is used to cover the peaks. The economics of the scheme depend on the terms under which private industry exports/imports electricity to and from the grid.

At present the electricity supply industry pays lower rates for its power stations compared with the rest of industry. It is also restricted by law to a 5 per cent profit. The supply industry only pays 60 per cent of the retail price of electricity to other companies exporting to the grid from private power units. Under these conditions there is little encouragement for private industry to invest in CHP schemes despite their greater fuel efficiency.

Q.8 An essential aspect of an economic CHP district heating scheme is a large, high density demand for heating.

CHP schemes are more common in countries such as Germany, Sweden, Denmark, Finland, Poland and Russia. Government financial support, and favourable investment criteria have encouraged the development of CHP and District Heating. These countries lack cheap natural gas. Many of them are dependent on expensive imported oil; they have stringent limits on chimney emissions and a cold climate.

Q.9 Householders are most likely to agree to take heat from a district heating (DH) scheme if it is cheaper than the alternatives, particularly gas-fired central heating. CHP/DH has been uncompetitive in this country because of the availablity of natural gas.

Q.10 *(a)* 294 MWh
(b) 294 MWh × 6 £/MWh = £1764
(c) 250 MWh
(d) 250 MWh × 12 £/MWh = £3000
(e) £4764

Q.11 *(a)* 375 MWh
(b) 375 MWh × 6£/MWh = £2250

Q.12 *(a)* £2514
(b) 8760 h
(c) £22 million

Q.13 £4.4 million

To be economic a CHP scheme needs to be assured of a steady demand for the energy for heating. In the case of industrial CHP the demand can be found close to the power station and there is no need for widespread distribution systems. There is also a much more steady demand for heating throughout the year.

The national grid makes it possible to balance the demand for electricity with the supply. Where possible the most efficient power stations are used. There is no corresponding area, or national distribution system, for hot water and steam and so there is a danger that a CHP scheme may have to generate electricity relatively inefficiently when there is low demand for the energy for heating.

Q.14 *(a)* £3.5 million
(b) £0.9 million
(c) 12.8 km

Installing district heating involves a substantial capital outlay and street disturbance. Most of the cost of installing the network of pipes is taken up with digging up the ground and then restoring the roads, pavements and gardens. Current estimates (1987) are that the cost is 5-10 £/kWh per km. The figure in the unit is at the low end of this range. A new CHP scheme in Leicester will involve a 13-km distribution system.

Acknowledgement Figure 1 supplied by the Central Electricity Generating Board.

WHY NOT COMBINED HEAT AND POWER?

This unit is in four parts:

Part 1 reminds you of the scientific meanings of power and efficiency.

Part 2 explains what is meant by 'combined heat and power' and shows that it can help to save fuel.

Part 3 introduces district heating.

Part 4 looks at the economics of combined heat and power (CHP) when linked to a district heating (DH) scheme.

Part 1 Power and efficiency

Most power stations generate electricity by burning coal or oil. Only just over a third of the energy from the fuel is converted to electricity. The rest is usually wasted.

Power stations cannot avoid wasting energy. It is **impossible** to make a machine or engine which will convert all the input energy to useful output energy. Some of the energy is always spread around in the surroundings and wasted.

Even so it is possible to make use of some of the energy which is lost. The problem is to find economical ways to do so.

Energy is supplied to the power station by the fuel. The **input power** tells you how **fast** the energy is supplied.

Useful energy leaves the power station electrically. The **output power** tells you how **fast** the energy leaves the power station.

The word **power** has a special meaning in science. Power tells you how fast energy is transferred.

Power is measured in **watts (W).** The power values for power stations are so big that they can be measured more conveniently in **megawatts (MW).** 1MW = 1 000 000 W.

In this unit you will be investigating the efficiency of different ways of supplying electricity and energy for heating. If a system is 100 per cent efficient, all the input power is available as useful output power. This is impossible in practice. The efficiency is always less than 100 per cent.

$$\text{efficiency} = \frac{\text{useful output power in MW}}{\text{input power in MW}} \times 100\ \%$$

Now answer question 1.

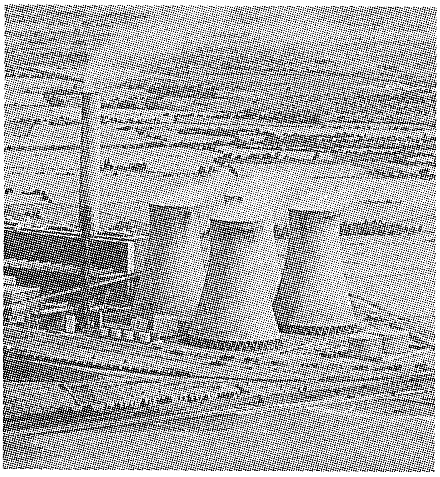


Figure 1 The huge cooling towers in this picture are used to get rid of energy from the cooling water. What a waste!

Question

1 Here are some sentences which include the word 'power'. Which of them use this word in its scientific way? Remember, the scientific meaning of power is 'rate of transfer of energy'.

(a) The prime minister is the politician with the most power in this country.

(b) This chain saw has so much power that it can cut through a big log in a few seconds.

(c) This spring has not got enough power to keep the door shut when a strong wind is blowing.

(d) This is such a powerful microscope that I can see very small bacteria with it.

(e) I have been feeling ill recently but the doctor gave me some medicine which did me a power of good.

(f) Fire engines need pumps with enough power to get lots of water into a burning building quickly.

(g) Judges have the power to put you in prison.

Part 2 What is combined heat and power?

First look at Figure 2 and answer question 2 to find the efficiency of a normal power station.

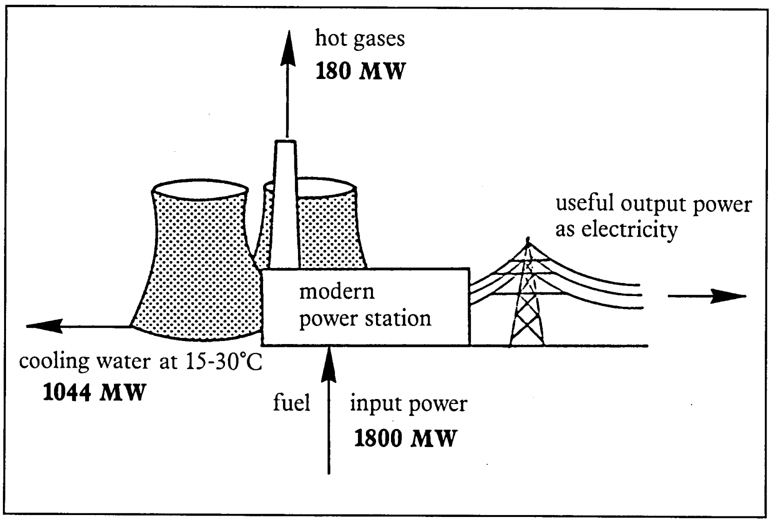


Figure 2

The idea of **combined heat and power (CHP)** is to use the energy from burning fuels more efficiently. CHP stations are built to supply electricity **and** energy for heating.

Hot water and steam from a CHP station can be used in industry. Figure 3 is based on a CHP scheme in Hereford. There are more than 150 industrial CHP schemes in Britain.

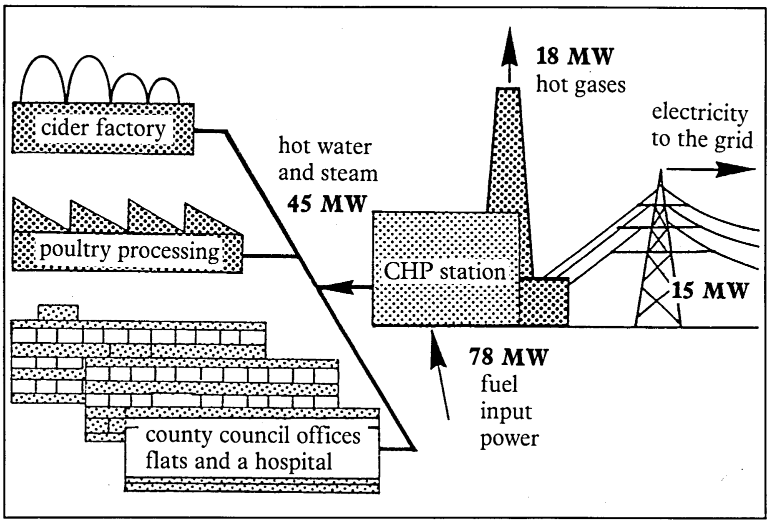


Figure 3

CHP stations are only worthwhile if there is a steady demand for heating as well as for electricity. This means that CHP is an attractive idea for industries which run all the time and always need hot water or steam. For example, heat is used for paper making, in the food industry and in the chemical industry.

Answer questions 3 to 7.

Question

2 *What is the efficiency of the normal power station shown in Figure 2? (Use the formula on page 1.)*

Questions

3 *(a) What would be the efficiency of the CHP station in Figure 3 if it was only supplying electricity? (Use the formula on page 1.)*
(b) How does the efficiency of the CHP unit compare with the power station in Figure 2 if you are just considering the generation of electricity?

4 *What would be the efficiency of the CHP unit in Figure 3 if it was only supplying hot water?*

5 *Calculate the efficiency of the CHP unit in Figure 3 when both electricity and hot water are taken into account.*

6 *Industry would use fuels more efficiently if there were more CHP schemes. What effect, if any, would this have on air pollution?*

7 *The Government could change the economic conditions to encourage more industries to install CHP schemes. Should they do so?*

Part 3 What is district heating?

CHP stations appear to be very efficient. It seems surprising that they are not used more in Britain. Why don't we use CHP to heat our homes?

District heating uses hot water from a CHP plant, or central boiler, to heat a large number of houses and flats (Figure 4). The hot water is fed to radiators and water heaters in the homes through pipes which are laid underground.

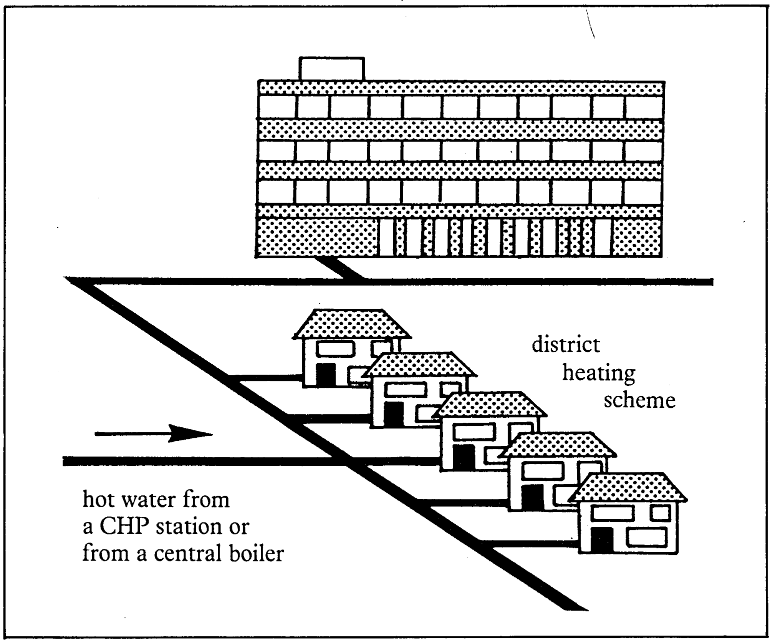


Figure 4

But there are few district heating schemes in Britian. There are several reasons for this:

- Central heating with hot water radiators has only recently become common
- Most people live in houses rather than blocks of flats (district heating is cheaper to install in blocks of flats)
- Natural gas is a cheap alternative in Britain

The use of combined heat and power is more common in other European countries. It is widely used for district heating in Germany, Sweden, Denmark, Finland and Poland.

Now answer questions 8 and 9.

At the moment natural gas is cheap. This means that it is usually not worth spending lots of money putting in the network of pipes needed for district heating. The price of fuels is expected to rise in future. This will possibly make CHP schemes more attractive.

Questions

8 Studies have been made which show that district heating could be economic in cities such as Belfast, Edinburgh, and Leicester. Why do you think that these places were found to be suitable for CHP schemes?

9 How would you and your family be affected if your home was connected to a district heating scheme? What might be the advantages and disadvantages?

Part 4 Is CHP with District Heating economic?

Figure 5 shows you a district of Britain which is being supplied with electricity in the normal way from **coal-fired** power stations. The heating for the district is assumed to be supplied by **gas-fired** boilers.

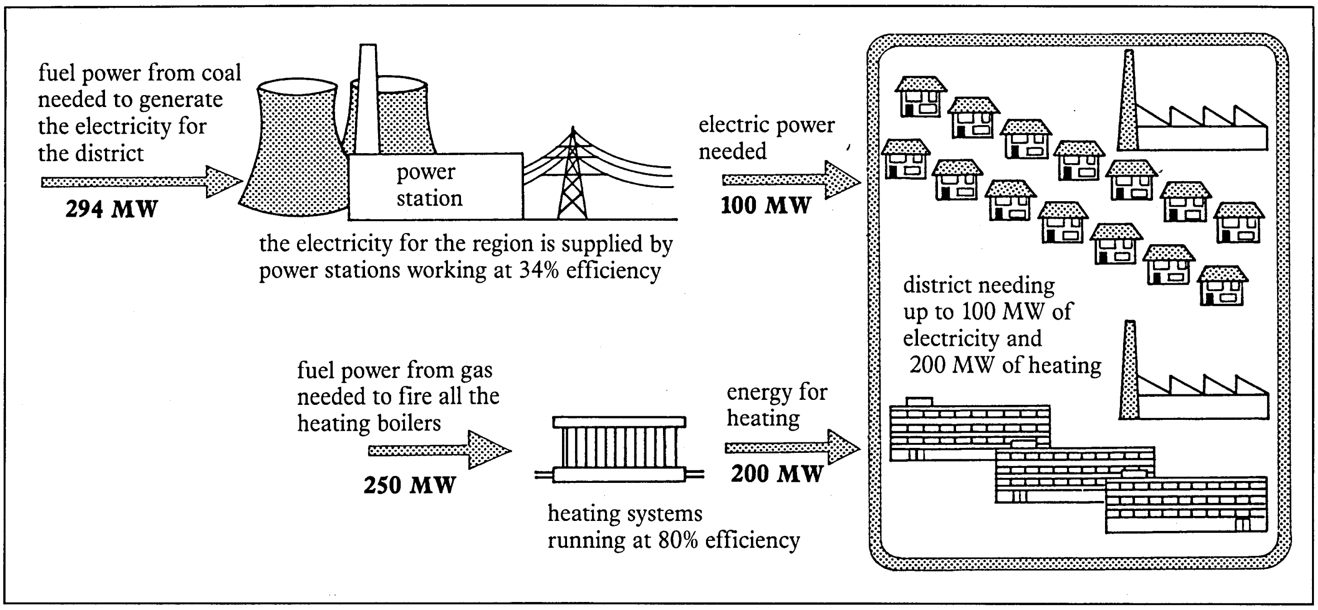


Figure 5 The energy supply for an imaginary district

Figure 6, on the next page, shows the same district being supplied with both electricity and energy for heating by a **coal-fired** CHP station.

In both schemes the power values assume that the heating systems are running at full capacity. This would only happen during cold weather in winter.

Use the information in the two diagrams to investigate the costs of running a CHP scheme with district heating. The questions will help you. You will find it helpful to use a calculator but remember that you are only making *estimates*. You should only give three significant figures.

Answer question 10.

Energy units

When one megawatt (1MW) power source runs for one hour, the amount of energy transferred is **one megawatt hour (MWh).**

In your calculations use the megawatt hour (MWh) to measure amounts of energy.

Costs of the fuels

The cost of energy from coal is £6 per MWh.
The cost of energy from gas is £12 per MWh.

Question

10 Consider the first scheme shown in Figure 6. Imagine the scheme running for ***one hour.***

(a) How many megawatt hours of coal are needed?

(b) What is the cost of the coal used?

(c) How many megawatt hours of gas are needed in one hour?

(d) What is the cost of the gas used?

(e) What is the ***total fuel cost*** *of running this scheme at full power for one hour?*

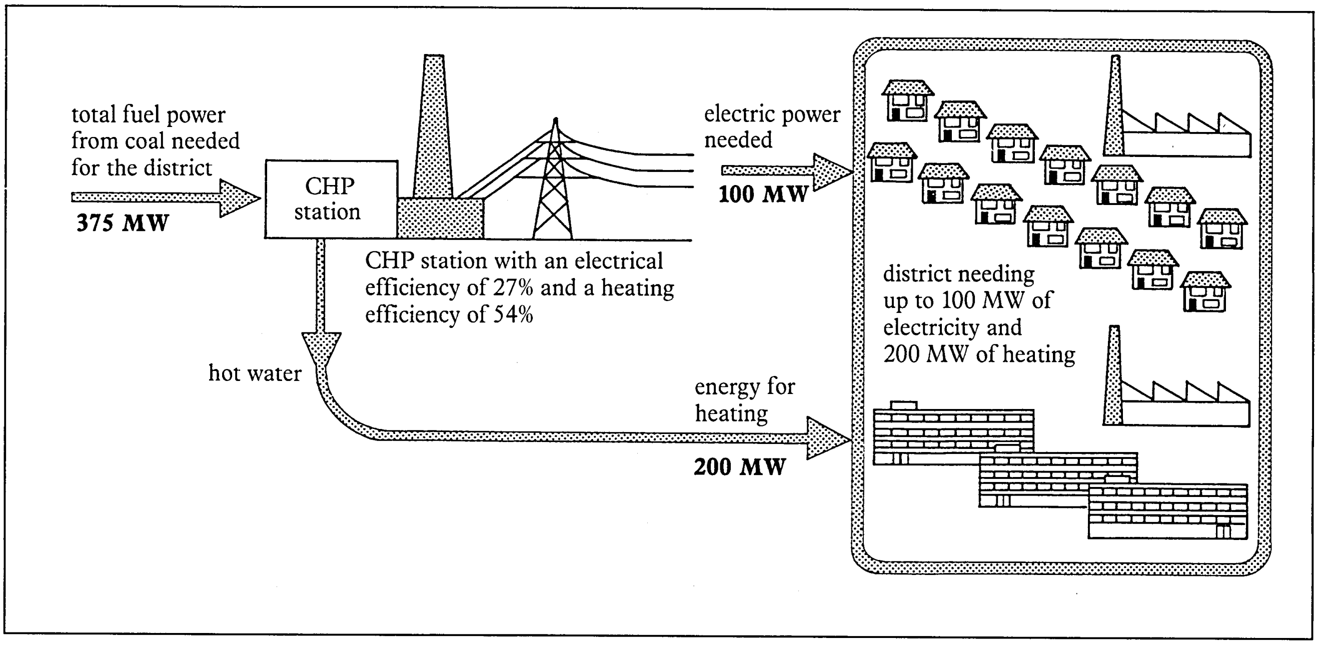


Figure 6 The same district as in Figure 5. Now the energy is being supplied by a CHP scheme.

Questions

11 *Consider the second scheme, shown in Figure 6. Imagine the scheme running for* **one hour.**
- *(a) How many megawatt hours of coal are needed?*
- *(b) What is the cost of the coal used? (This is the total fuel cost of running this scheme at full power for one hour.)*

12 *(a) How much money is saved each hour by the CHP scheme?*
- *(b) How many hours are there in a year?*
- *(c) What would be the saving in a year if the scheme ran at full power night and day?*

13 *In fact the CHP will only be used for heating at full power for part of the year. The* **average** *rate of heating over a year will be around 40 MW. So the money saved in a year will only be about one-fifth of your answer to 12(c). How much money will be saved in a year at this rate? (Convert your answer to £million. Give your answer to two significant figures.)*

14 *(a) The extra cost of building the new CHP station for this district is £50 million. This can be paid for by a loan. How much has to be paid back each year to the lender of the money?*
- *(b) How much is left from the savings calculated in question 13 after you have paid for the loan?*
- *(c) How much pipework can you afford for a district heating scheme?*

15 *What do you conclude about the economics of CHP schemes from your answer to 14(c)? (Look back to your answer to question 8.)*

Capital costs for CHP

A loan of £50 million will be needed for the extra cost of a new CHP station. This can be paid back over 25 years at an interest rate of 5 per cent.

This means that a payment of **£3.5 million** has to be made **each year** to the lender of the money.

Capital costs for district heating

Installing the pipework for a district heating system of this size costs about £1 million per kilometre.

This means that **£0.07 million** has to be paid **each year** for **each kilometre** of pipeline.