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.

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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.

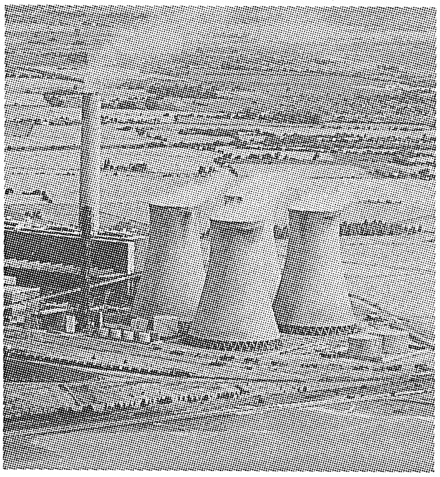

Figure 1 The huge cooling towers in this picture are used to get rid of energy from the cooling water. What a waste!

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.

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.

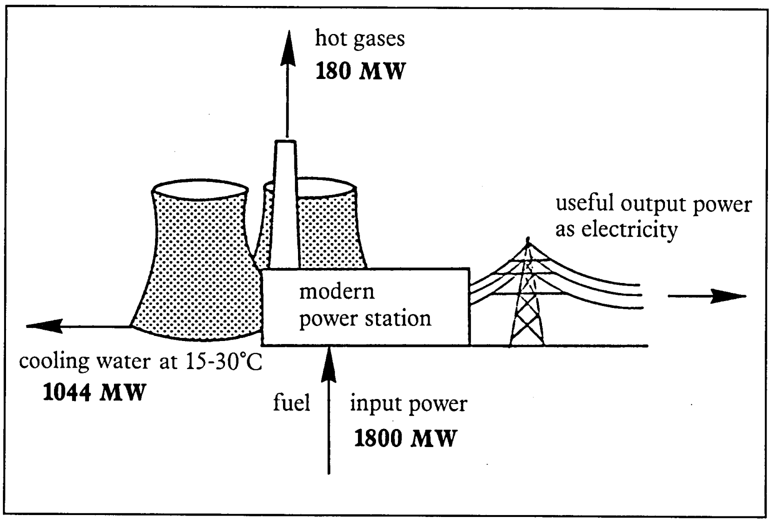

Figure 2

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

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.

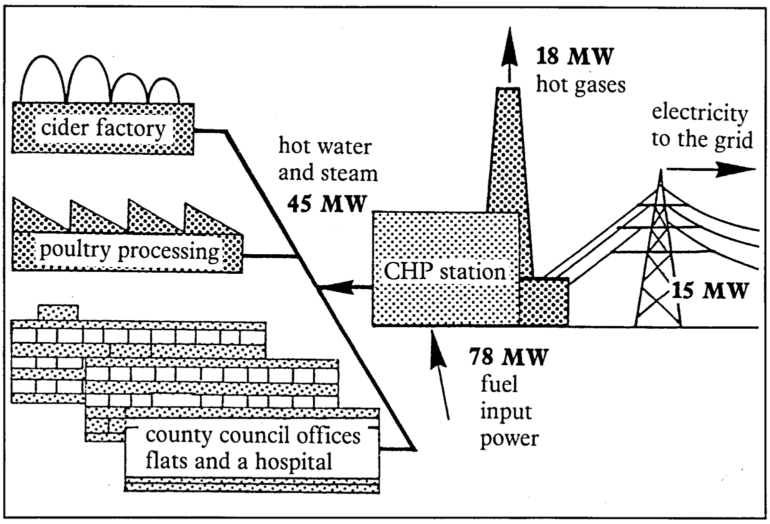

Figure 3

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.

> *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.

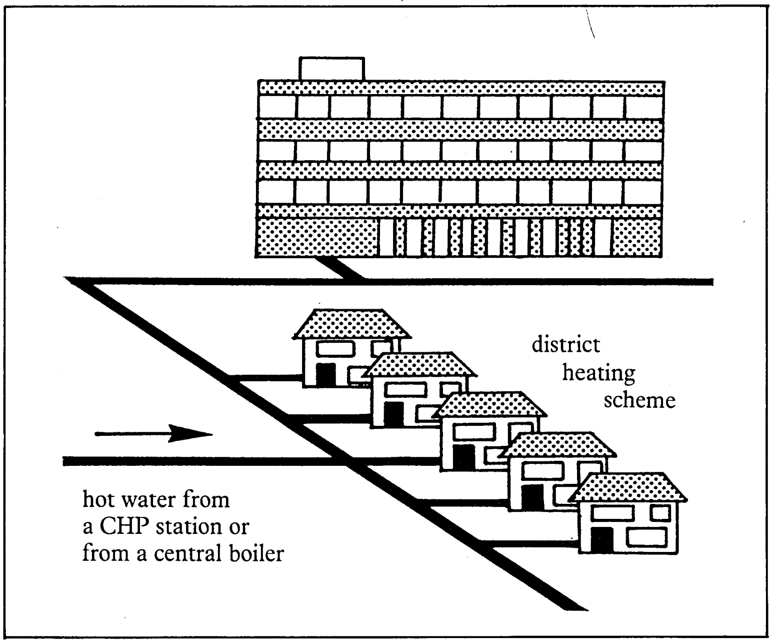

Figure 4

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.

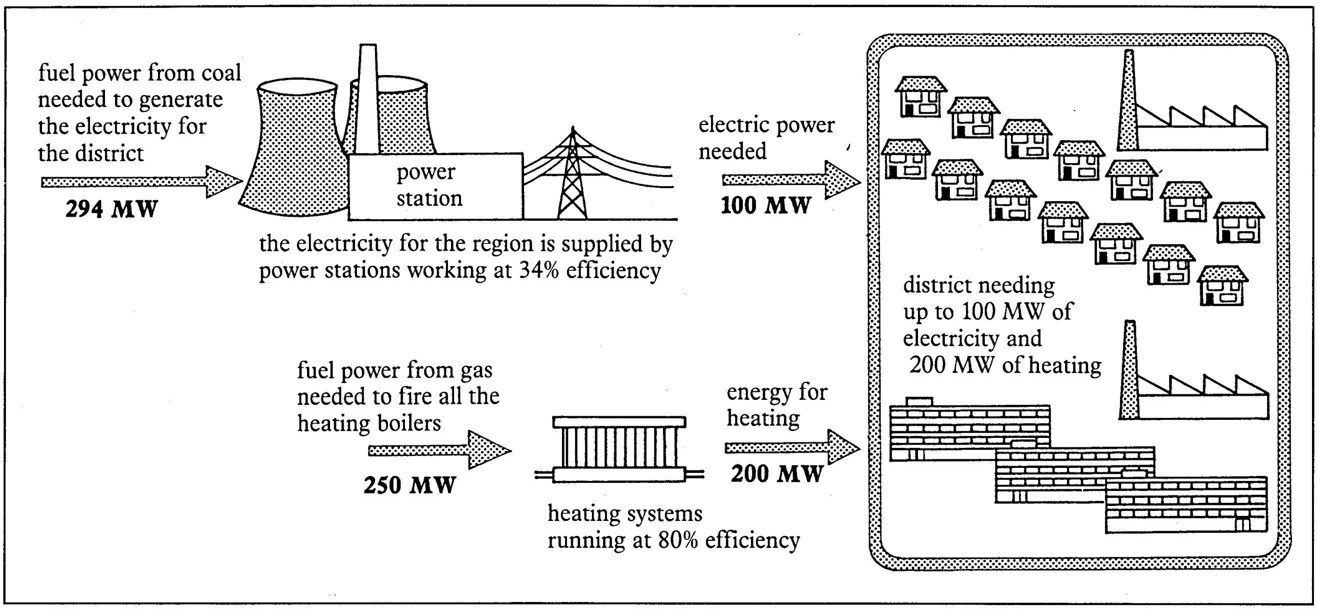

Figure 5 The energy supply for an imaginary district

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?*

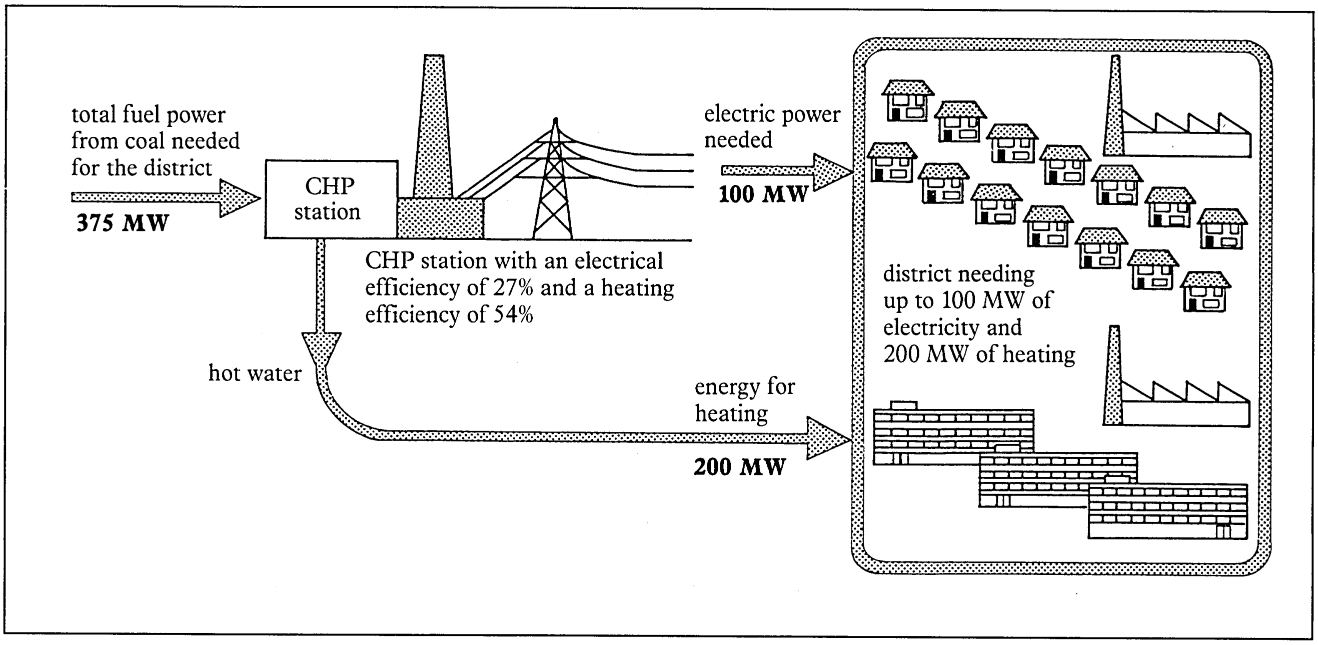

Figure 6 The same district as in Figure 5. Now the energy is being supplied by a CHP scheme.

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.