ELECTRICITY supply and demand

Science content

Energy sources for power stations, distribution of electric power on a national scale.

Science curriculum links
AT11 Electricity and magnetism
AT13 Energy

Syllabus links
- GCSE Science, Physics
- Geography
- Sixth-form General Studies

Lesson time
2 hours

Links with other SATIS materials
701 Electricity in Your Home
704 Electric Lights
1007 240 Volts can Kill
1008 Why 240 Volts?
1010 Can it be done? (questions 12, 13, 34)

SATIS 16–19
25 Why 50 Hz?

BBC Radio SATIS Topics 14–16
Electricity on Demand

NERIS
Search on
ELECTRIC POWER GENERATION
and POWER STATIONS
or on POWER STATIONS and ENERGY SOURCES

SUMMARY

This unit has been developed from SATIS 601, *Electricity on Demand*, which it replaces. It is set in the context of the restructured electricity supply industry. Questions and graphical work have been added to the text prior to the decision-making task.

STUDENT ACTIVITIES

- ☐ Home survey, reading, interpreting graphs and answering questions: the information relates to home demand, the National Grid, demand curves, types of power station.
- ☐ Problem-solving task for pairs: a Regional Control Centre simulation – planning the deployment of power stations to meet demand curves (cut and stick data supplied).

AIMS

- ☐ To complement prior work on electricity generation and energy transfer
- ☐ To describe the different types of power stations in use in Britain, and their relative advantages and disadvantages
- ☐ To show the planning decisions that have to be made to ensure a reliable and economic supply of electricity on demand
- ☐ To provide opportunities for data interpretation, planning and decision-making

USING AND ADAPTING THE UNIT

- ☐ Suitable for a wide range of abilities. May be used in conjunction with work on the generation and distribution of electrical power.
- ☐ Some teachers use the material as a source of information on the electricity supply industry and omit the task at the end.
- ☐ Activity A is optional.
- ☐ The supporting BBC Radio programme visits the London Control Centre to witness the 'TV pickup' after 'Neighbours'. The programme explains that frequency is high when too much electricity is being generated and falls when demand fails to meet supply. The programme is best used along with the section *Meeting the demand* on page 3.
- ☐ Less able students may need support with the task in part C, otherwise they tend to meet the demand with a random selection of power stations.

Consultant **Alan Attwood**
Developed from SATIS 601, *Electricity on Demand*, (1986).

Published 1991

Other resources

A Town Like Wattville from the Electricity Association is a software package that contains a large data base together with graphical, numerical and spreadsheet presentations. It enables students to simulate electricity use in a modern city on a BBC microcomputer. It is available from The Electricity Association, 30 Millbank, London SW1P 4RD. Tel. 071-834 2333.

How Electricity is Made is a video that deals with the generation of electricity in power stations. It is available on free loan from Barbara Steinberg, Film and Video Officer, National Power, Film and Video Library, Sudbury House, 15 Newgate Street, London EC1A 7AU. Tel. 071-634 6337.

Further information

The electricity supply industry has been divided into:

- the National Grid Company which is responsible for transmission at 400 kV and 275 kV,
- twelve Regional Electricity Companies,
- the generating companies, National Power, PowerGen and Nuclear Electric. Nuclear Electric is responsible for nuclear power stations and remains a nationalised company. Other companies may offer electricity to the National Grid. There is a future commitment that 600 MW will be from renewable resources by 1998. (This is not much compared with a 1990 installed capacity of 52 000 MW.)

The *marginal* cost of generating from nuclear power, which is mainly the fuel cost, is still far lower than from any fossil fuel. It is the *capital* cost that now appears high. Only marginal costs contribute to decision-making in part C of this unit.

The generating companies offer electricity to the National Grid Company on a daily basis. Pricing is done in half hour periods. Power stations whose offers are lowest in price are used. Within each half hour, the final price paid to all generating companies is the same and is linked to the highest price chosen to meet the demand in that period.

Answers to the questions

Q1 *(a) 1000 V = 1 kV*

Q2 *(a) 25 000 V*
(b) 400 kV and 275 kV
(c) 132 kV, 33 kV, 11 kV, 240 V (the p.d. from phase to phase of the 3-phase supply is 415 V).

Q3 *1 000 000 W = 1 MW*

Q4 *(a) People getting up, making breakfast, turning on lights etc.*
(b) People cooking an evening meal, turning on electric appliances at home.
(c) Industry, commerce, transport, schools etc. running through the day but not the night.

Q5 *(a) People using electrical appliances before settling down to a day watching TV.*
(b) Most people watching TV (which does not use much electricity) to catch a first glimpse of the bride and her dress – about which there was much speculation.

Q6 *On the Royal Wedding Day, demand rose as usual but peaked somewhat lower (approx 20 GW instead of a typical 28 GW), suggesting many factories had the day off work. Demand then fell dramatically and remained uneven with periods of TV pickup.*

Q7 *Hydro and nuclear in particular. Coal and oil may be used if the price of these fuels is low.*

Q8 *Pumped storage, gas turbine. Coal and oil may also be used.*

Q9 *Dinorwig is using electricity to pump water uphill.*

Q10 *As graph rises from points (1) 2, 3, 4, 5, 6, 7 and 8 on the graph.*

Q11 *(a) (i) hydro, (ii) oil.*
(b) Fiddlers Ferry

Q12 *(a) 3200 MW, (b) just before 10.00.*

Q13 *3600 MW.*

Q14 *5/4 times the price of energy used to pump it up.*

Acknowledgements

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Figure 3 is reproduced by permission from *Science* by Graham Hill and John Holman (Nelson).

Figure 6 is reproduced by permission of PowerGen.

ELECTRICITY supply and demand

Part A: Supplying electricity
Part B: Types of power station
Part C: A decision-making task for students working in pairs.

Part A – Supplying electricity

Think how often you switch on a light, the TV or electric kettle! Each time you do it, you create a demand for electricity.

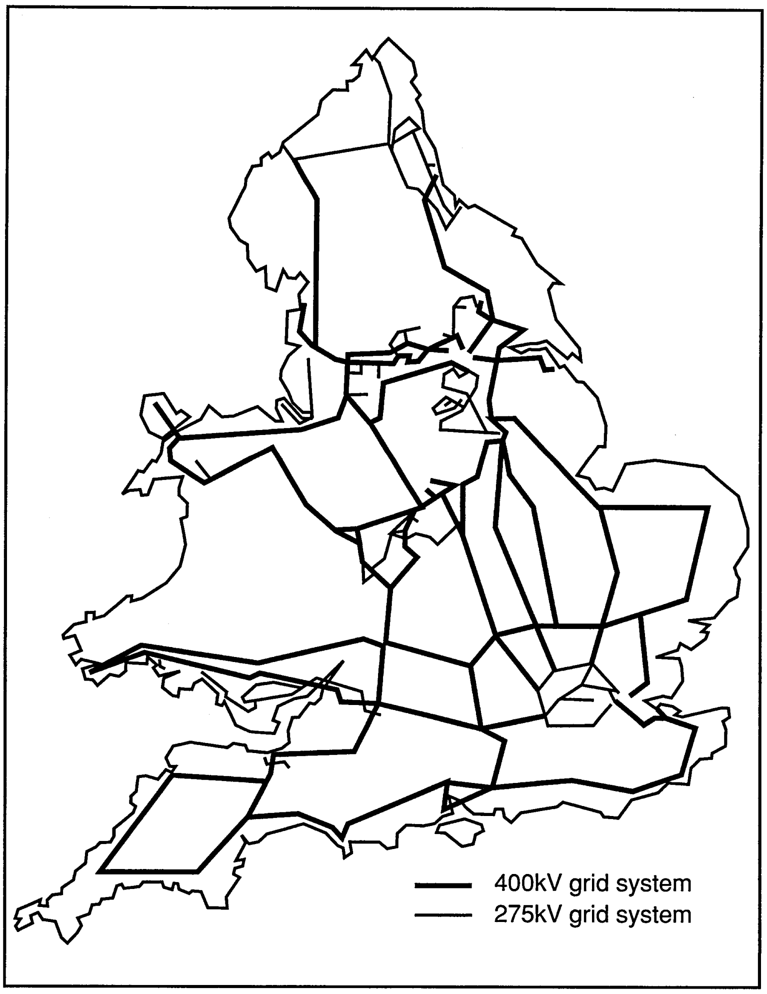
The **National Grid Company** (NGC) has the job of matching the supply of electricity to the demand in England and Wales.

In part C of this unit you will be able to simulate the job of engineers in the Control Centre of North West Region (figure 1). Your task will be to meet the demand for electricity at the lowest possible cost.

Electricity supply and the National Grid

Electricity is produced in power stations. They are linked into a network of power lines called the **National Grid** (figure 2).

Figure 2 The National Grid



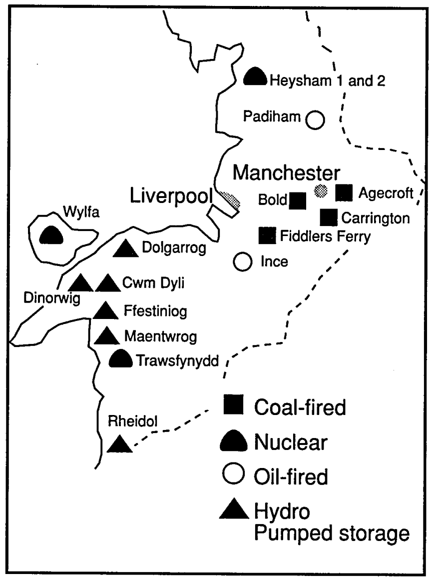


Figure 1 Power stations in the North West Region

Activity A

A survey to do at home

How many times do you switch on mains electricity?

☐ Try counting the number of times you *switch on* in an evening between 6 p.m. and bedtime. Combine the results of the class and plot a histogram.

☐ Or count how many times an hour your family *switches on* in a 24-hour day. Are there any appliances that are switched on all the time? How are you going to count them?

Draw a graph of your results.

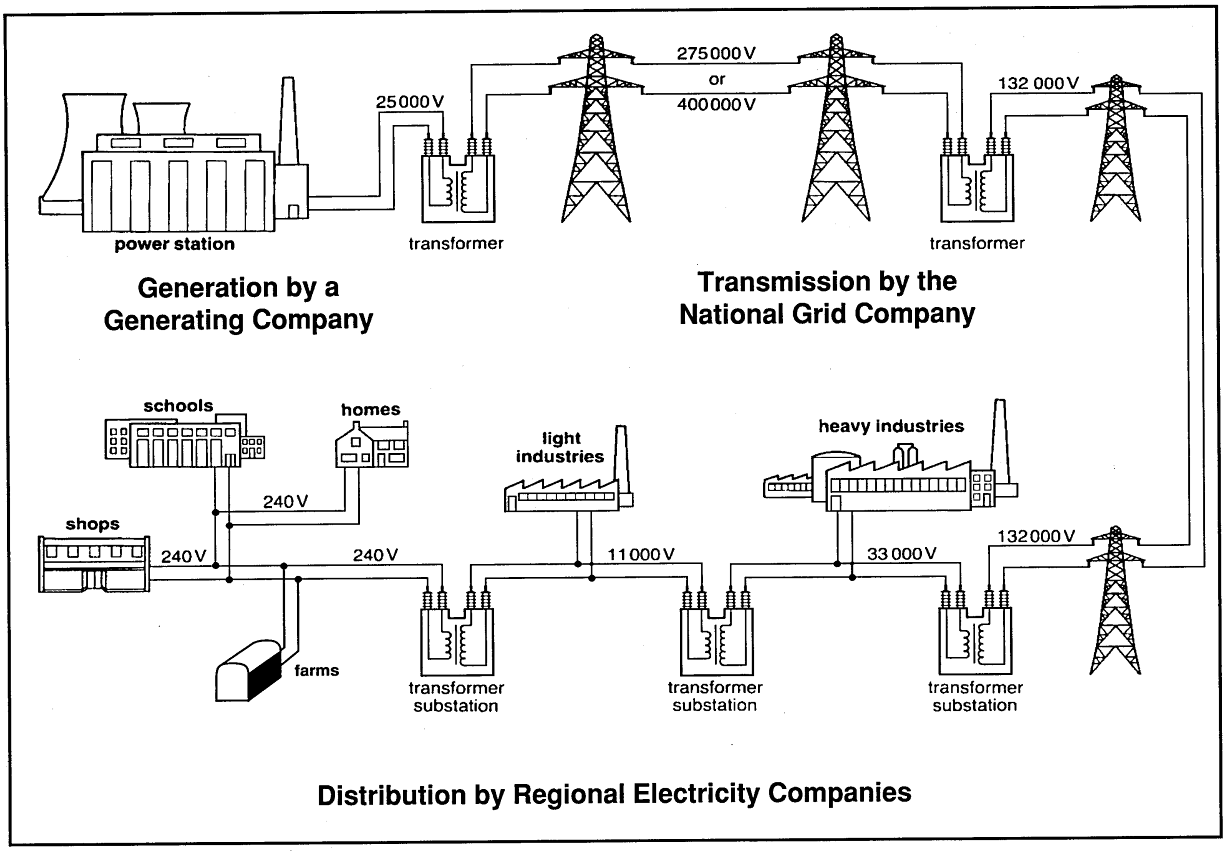


Figure 3 The transmission and distribution system

> ***Questions on part A***
>
> ***Q1*** *How many volts (V) are in a kilovolt (kV)?*
>
> ***Q2*** *Look at figure 3 showing the transmission and distribution system.*
> *At what voltages is electricity*
> *(a) generated,*
> *(b) transmitted on the National Grid,*
> *(c) distributed by the Regional Electricity Companies?*
>
> ***Q3*** *The output of power stations is given in megawatts (MW). How many watts (W) are in a megawatt?*

The National Grid is used to **transmit** electricity around the country to where it is needed. Transmission is at 400 kilovolts or at 275 kilovolts. The very high voltage allows a lot of energy to be transmitted and saves on energy wasted in power lines.

Transformers are used to step down the voltage to 132 kilovolts for local distribution by the **Regional Electricity Companies**.

The National Grid Company must balance the supply of electricity with the demand for electricity. It tries to do so at the lowest possible cost. It instructs the power stations (owned by the Generating Companies) how much electricity to generate minute by minute as the day goes by.

Britain has a variety of power stations, mostly coal, oil, nuclear and hydro. The cost of producing electricity in each power station is different. The cheapest power stations are used all the time as the **base load**. The more expensive power stations are used when demand is high – for example, at dusk in winter when people turn on lights.

Power stations differ in the amount of electricity they can generate. In the North West Region, the smallest produces only 10 megawatts of power, the largest generates 1900 megawatts when all its four generators are running.

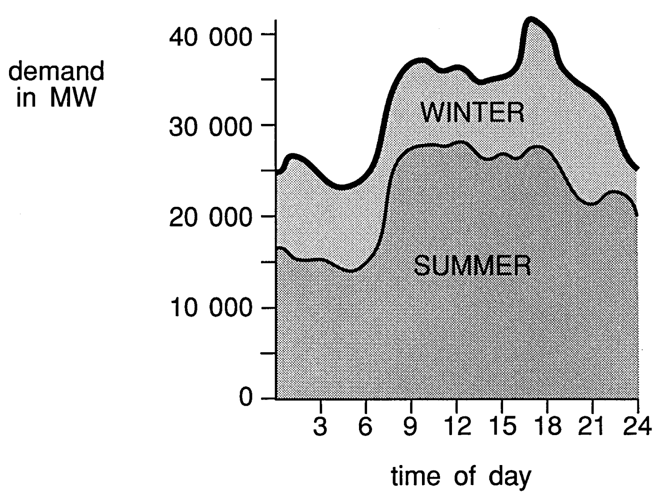
Meeting the demand

Electricity is generated as it is needed. If people want more electricity than the generating companies can supply at any moment, there have to be voltage reductions or power cuts.

The demand for electricity varies enormously from night to day and from summer to winter (figure 4). Engineers in the Control Centres watch the demand very carefully and try to predict what it will be. They study weather forecasts and follow television programmes. After a popular TV programme like 'Neighbours' there is a sudden surge in demand – known as 'TV pickup'.

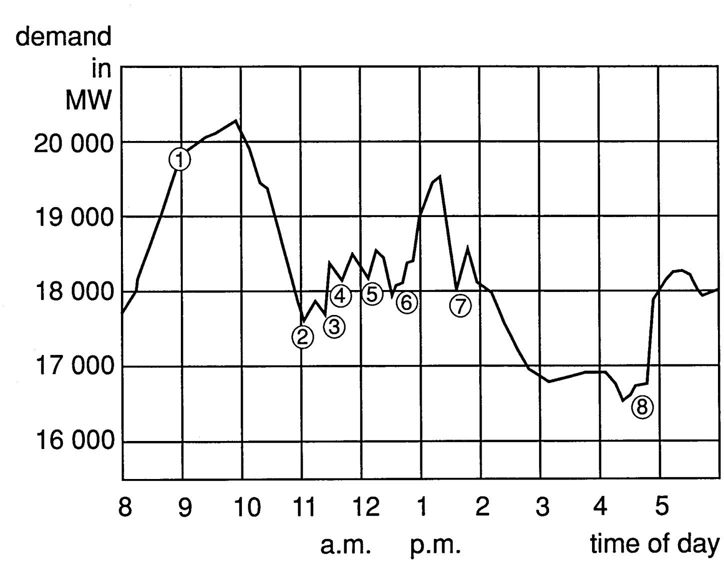
The demand curve in figure 5 was for a day in which the Nation behaved differently. Fortunately, the engineers predicted what would happen.

Figure 4 Demand curves for typical summer and winter days



> ***Q4*** *Look at figure 4. Suggest why the demand*
> *(a) rises between 6.00 and 9.00,*
> *(b) peaks between 17.00 and 18.00,*
> *(c) remains higher during the day than the evening.*
>
> ***Q5*** *Look at figure 5, the demand curve for the Royal Wedding Day 1981.*
> *(a) Suggest why the demand for electricity was (i) high at 10 a.m., (ii) low at 11 a.m.*
> *(b) Which parts of the curve clearly show 'TV pickup'?*
>
> ***Q6*** *Describe the differences between the demand curve for a typical summer day and that of the Royal Wedding Day.*

Figure 5 Changes in demand for electricity during Royal Wedding Day, 1981



Notice how the demand jumped after each high point of the wedding, as people left their TVs to switch on kettles etc.

1 Television broadcast sets the scene
2 The bride's arrival at the altar
3 End of the marriage
4 End of prayers
5 Signing the registers
6 Procession returns to Buckingham Palace
7 Last appearance of the couple on the royal balcony
8 Couple leave Waterloo Station

Part B – Types of power stations

1 Coal fired power stations

Coal-fired power stations are often sited near Britain's major coal fields to save moving coal long distances. Almost all small coal-fired power stations have now been closed.

It takes many hours to start up a coal-fired power station so their use has to be carefully planned in advance. However, they can be run at less than full load so that they can pick up their full output in minutes if needed. Coal-fired power stations are usually cheaper to run than oil-fired stations.

Sources of energy used for electricity generation in Britain in 1989

Coal	63%
Oil	7%
Nuclear	19%
Hydroelectricity	2%

(Electricity imported from France by cable under the Channel 4%.)

2 Oil-fired power stations

Oil stations are used flexibly because the price of oil is unpredictable. They are run as base load when oil is cheap, for daily load (on and off once a day) as prices rise and for peak load (on and off for just two or three hours at a time) when prices are high.

3 Nuclear power stations

Once they have been built, nuclear power stations make electricity fairly cheaply. They are used to provide the base load.

4 Gas turbine power stations

Both Heysham and Fiddlers Ferry power stations also have gas turbine generators. They are based on gas turbine aero-engines burning aircraft fuel. Although cheap to build they are very expensive to run. They can be started up in a few seconds and are used at moments of peak demand.

There are plans to build combined cycle gas turbine power stations in Britain. These burn natural gas and use the heat to drive gas and steam turbines. They are 40 – 45 per cent efficient and produce little pollution. However, some people think that gas should not be used for electricity generation when other fuels are available.

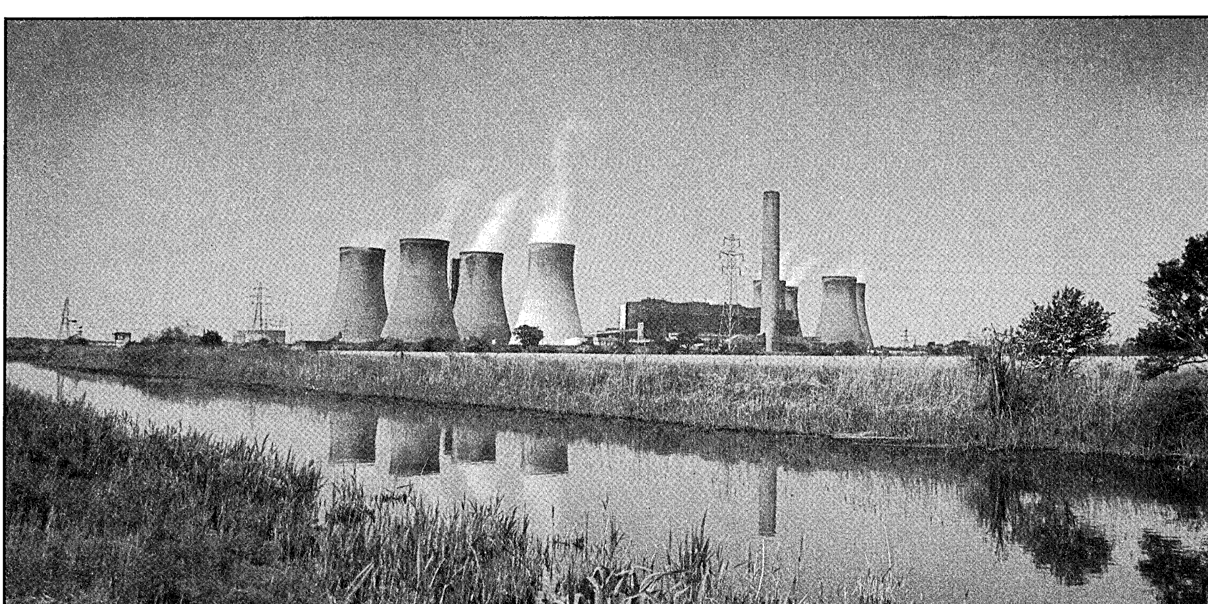


Figure 6 Fiddlers Ferry coal-fired power station

5 Hydroelectric power (HEP) stations

Hydroelectric power stations provide very cheap electricity. Although they use renewable energy, hydroelectric schemes may flood beautiful valleys. Plans to build them often meet with strong opposition. In the North West Region there are a few small hydroelectric power stations in North Wales.

6 *Pumped-storage*

The North West Region has two **pumped-storage schemes**. They provide a way of storing energy when demand in low, ready to turn it into electricity when demand is high. Overall efficiency is about 80%. Pumped storage power stations are used for peak demand – when extra electricity is needed for a short time.

Pumped storage power stations are 'reversible'. They can work as hydroelectric power stations and generate electricity. Or, their generators can be used as motors to drive their turbines which then act as pumps. When demand for electricity is low, usually during the night, they receive electricity from the Grid and pump water up to the top reservoir, converting electrical energy into gravitational potential energy (g.p.e.). When they are generating, they convert gravitational potential energy into electrical energy again.

There are two pumped-storage stations in the North West Region, both in the mountains of Snowdonia. The larger one is at Dinorwig. Dinorwig can be 'switched on' in 10 seconds and can generate 1800 megawatts for up to 5 hours.

Questions on part B

Q7 Which types of power station are best used all the time?

Q8 Which types of power station are best used only for times of high demand?

Q9 Why does Dinorwig power station use electricity at night rather than generate it?

Q10 Look back at figure 5, the Royal Wedding Day. Suggest at least two times of day when you think Dinorwig pumped storage power station may have been needed to generate electricity.

Figure 7 How a pumped storage scheme works

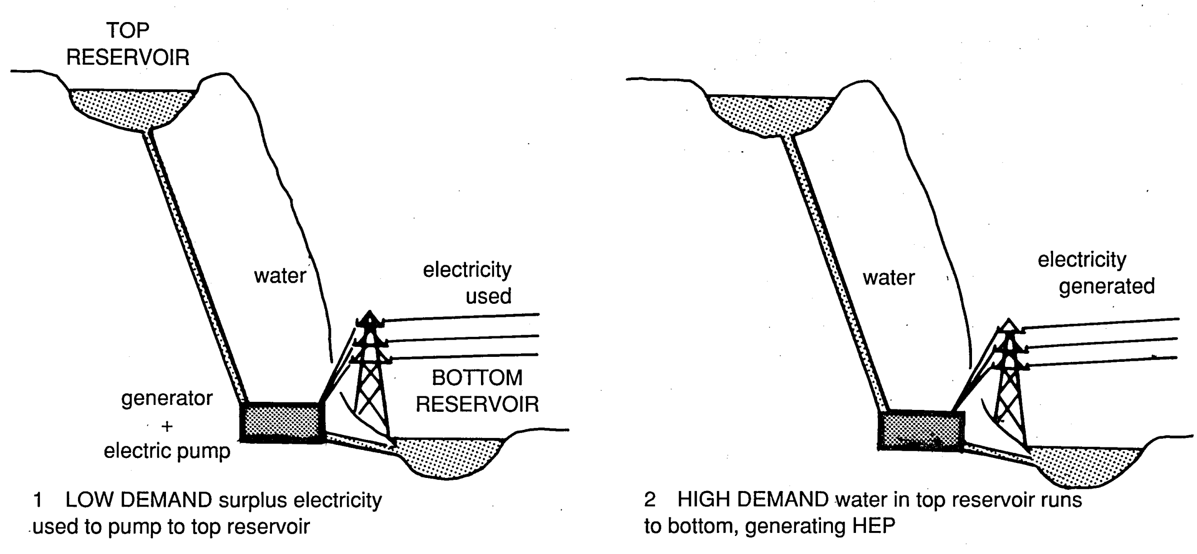


Table 1 Power stations in the North West Region

Name of power station	Type	Normal output in megawatts	Fuel cost per megawatt-hour
Heysham 1	Nuclear	1320	£7.00
Heysham 2	Nuclear	1320	£6.50
Trawsfynydd	Nuclear	380	£8.00
Wylfa	Nuclear	800	£7.50
Agecroft	Coal	215	£18.50
Bold	Coal	160	£21.00
Carrington	Coal	230	£21.00
Fiddlers Ferry	Coal	1900	£15.00
Ince B	Oil	1000	£26.00
Padiham	Oil/Coal	200	£26.00
Cwm Dyli	Hydro	10	Nil
Dolgarrog	Hydro	25	Nil
Maentwrog	Hydro	24	Nil
Rheidol	Hydro	50	Nil
Dinorwig	Hydro/Pumped-storage	1800	Nil*
Ffestiniog	Hydro/Pumped-storage	360	Nil*

* For the pumped-storage stations, fuel costs are nil when generating. When pumping water up, fuel costs depend on which other power stations are running.

Questions on part C

Q11 (a) Which types of power station are the (i) cheapest, (ii) most expensive in fuel costs?
(b) Which is the cheapest coal-fired power station to run?

Q12 Look at the summer demand curve in figure 9.
(a) Find the demand for electricity at 06.00.
(b) At what time of day is demand highest?

Q13 Look again at figure 9. What is the least amount of power you need to be sure of meeting the demand between 00.00 and 06.00?

Part C – Deciding which power stations to use

It is best to work on this part in pairs.

Imagine you are engineers working for the National Grid Company. You are based at the Regional Control Centre. Your job is to make sure enough electricity is generated, *at the lowest possible cost.*

The generating companies tell you the price of electricity from each of their power stations. The prices are given in the table above.

Answer question 11.

Look at the demand curve for a typical summer day in figure 9.

Answer questions 12 and 13.

Your task

Start with a typical summer day (figure 9). Plan which power stations to use during each 6 hour period of time. (00.00 to 06.00; 06.00 to 12.00; 12.00 to 18.00; 18.00 to 24.00.)

The amount of power each station produces has been drawn to scale in figure 11. You can cut out these rectangles and put them on the demand curve to help you. An example (figure 8) has been started for you.

- □ You must choose power stations to give electricity at the lowest cost. Remember that some power stations are more expensive to run than others.
- □ You must generate exactly as much power as you need at any time. But you cannot know precisely how much that will be – so you must always keep a bit of generating capacity in reserve.
- □ Remember that some power stations can be started up quickly when there is a sudden demand for electricity. Others, like nuclear, are best kept running all the time.
- □ When demand is low, you can use surplus electricity to store energy with pumped-storage stations. You can use this stored energy at high demand times.
- □ Draw in the power stations as you plan each 6 hour period, so that you have a record of what you decided.
- □ Do the task for summer first (figure 9), then winter (figure 10).

A more difficult question

Q14 *When you have finished, see if you can work out a price for electricity from pumped storage knowing that efficiency of pumped storage is 80%.*

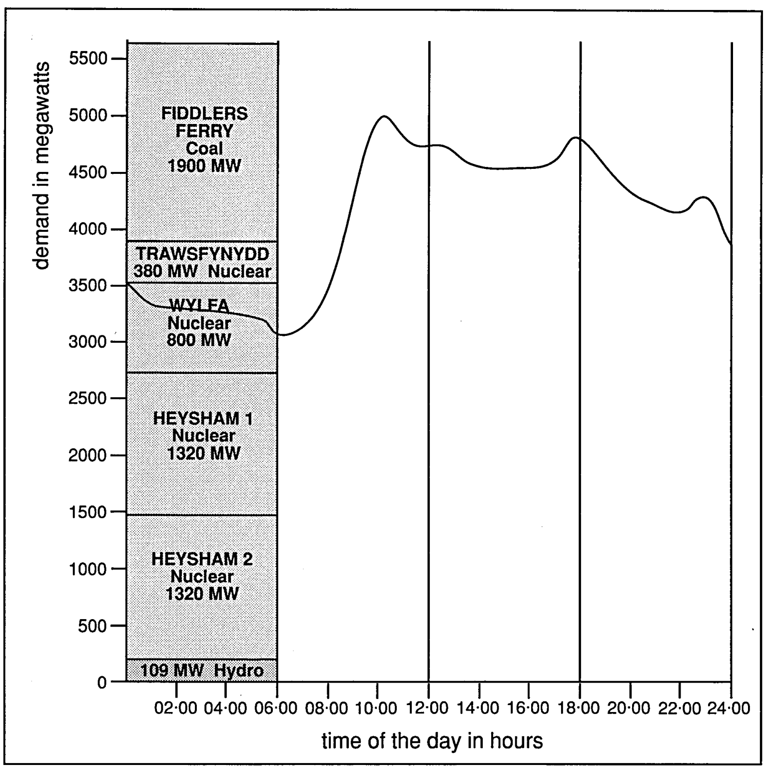


Figure 8 Using the cut-out blocks from figure 11

You have worked with fixed prices and 6 hour blocks of time. In real life, the prices of electricity for the Grid may change every half hour.

Engineers in the Control Centre must make minute by minute decisions as to which power stations to use.

Figure 9

Summer day demand curve

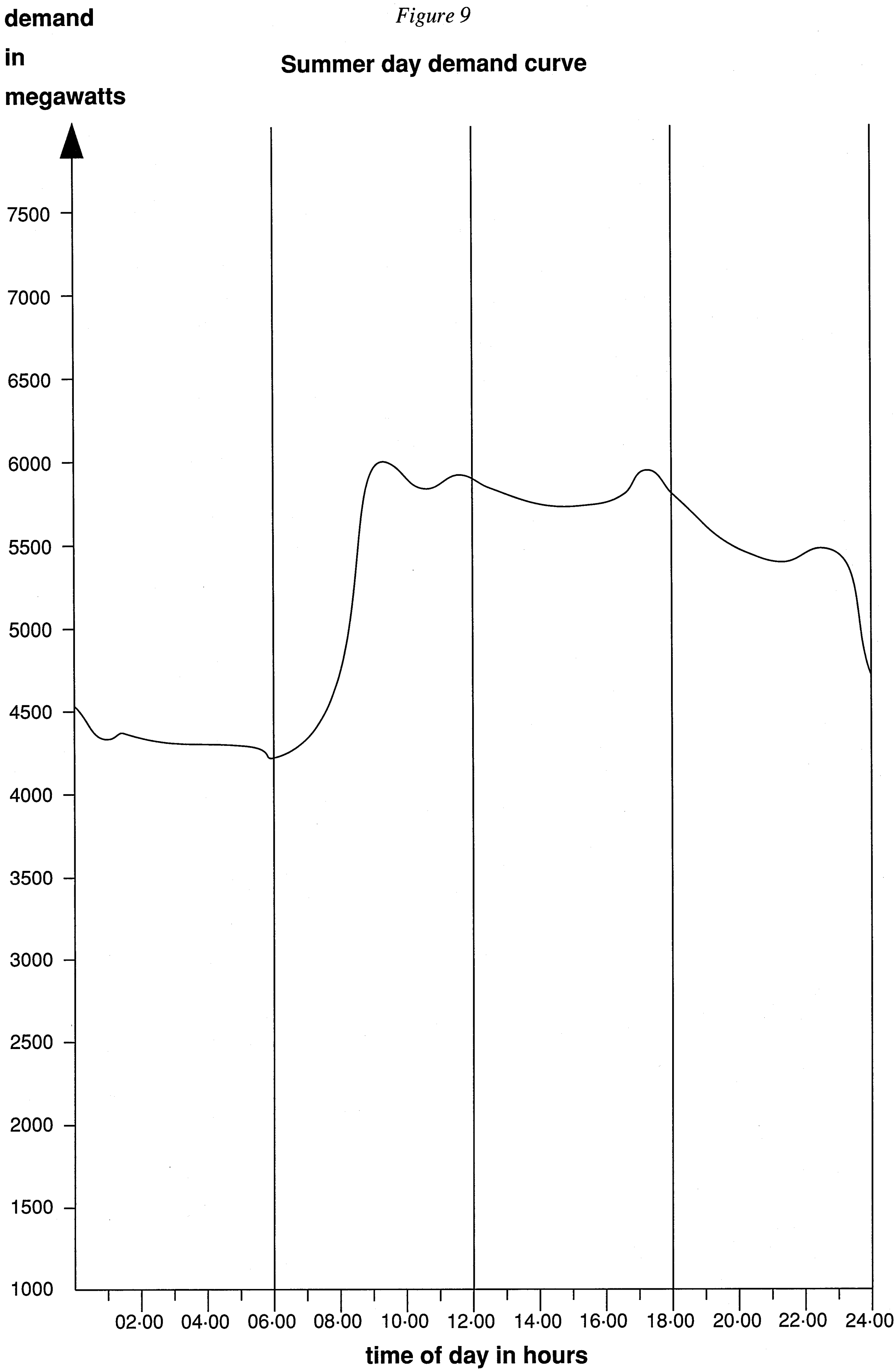


Figure 10

Winter day demand curve

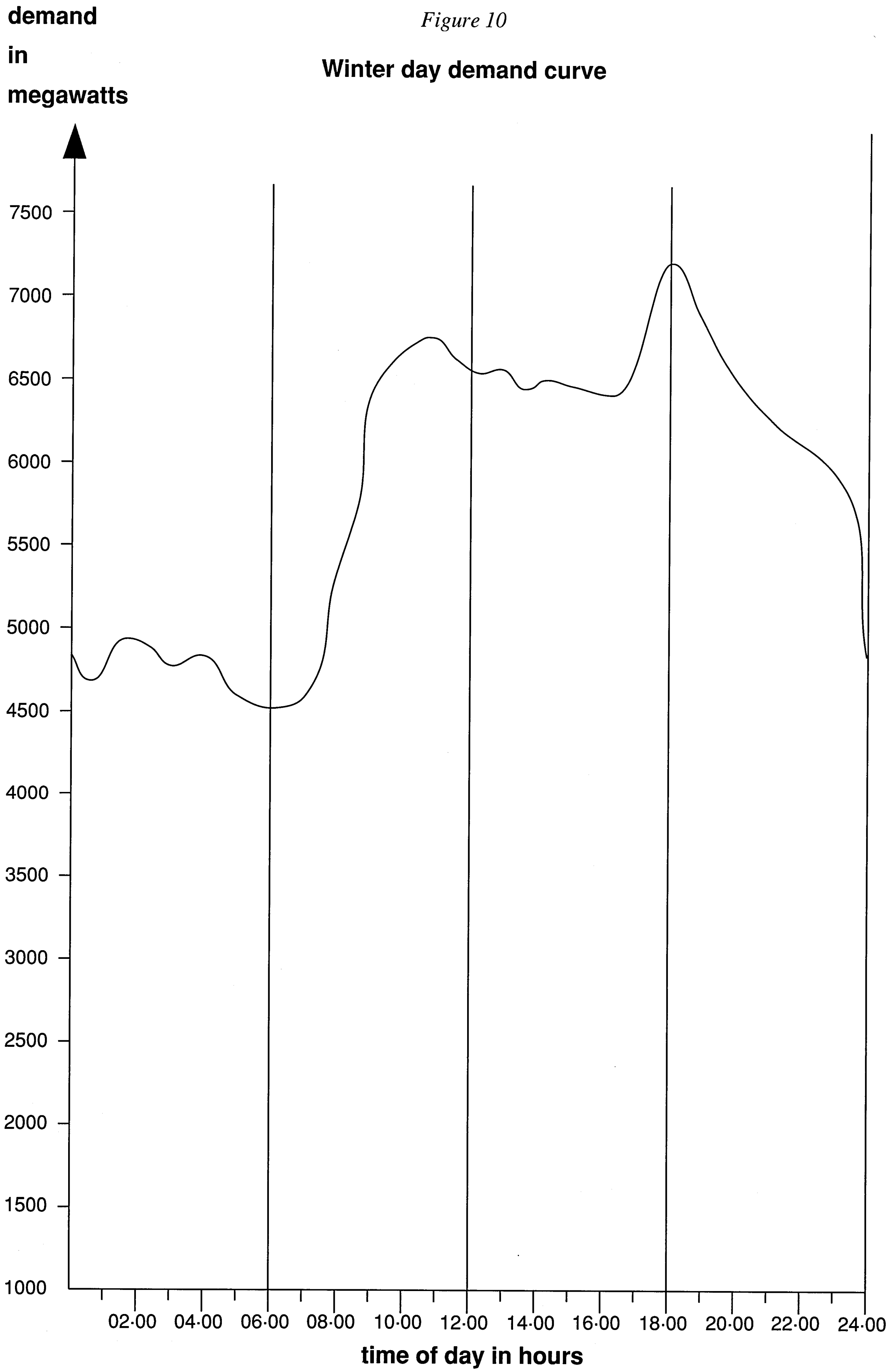


Figure 11 Blocks to represent power station generating capacities. Cut them out to help you with the task

NUCLEAR

Heysham 1
Nuclear
1320 MW
£7.00 per MWh

Heysham 2
Nuclear
1320 MW
£6.50 per MWh

Wylfa
Nuclear
800 MW
£7.50 per MWh

Trawsfynydd
Nuclear 380 MW
£8.00 per MWh

COAL

Fiddlers Ferry
Coal
1900 MW
£15.00 per MWh

Agecroft
Coal
215 MW
£18.50 per MWh

Bold
Coal
160 MW
£21.00 per MWh

Carrington
Coal
230 MW
£21.00 per MWh

OIL

Ince B
Oil
1000 MW
£26.00 per MWh

Padiham
Coal/Oil
200 MW
£26.00 per MWh

HYDRO and PUMPED STORAGE

Cwm Dyli, Dolgarrog
Rheidol, Maentwrog
Hydro
Total 109 MW
£nil per MWh

Ffestinlog
Hydro/Pumped
storage
360 MW
£nil per MWh

Dinorwig
Hydro/Pumped
storage
1800 MW
£nil per MWh