Science In a Social CONtext

ENERGY: THE POWER TO WORK

John Holman

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ASSOCIATION FOR SCIENCE EDUCATION
BASIL BLACKWELL · PUBLISHER

Acknowledgements

Joan Solomon would like to thank many friends and pupils for their invaluable help and comments, and particularly the many teachers who participated in the SISCON-in-Schools project and tried out these materials in their schools and colleges.

The publishers would like to thank the following for permission to reproduce illustrations on pages: 38 AERE, Harwell; 36 Ron Bailey LRPS; 22 British Nuclear Fuels Ltd.; 37 National Tourist Organisation of Greece; 41, 43 Oxfam; 24, 25 United Kingdom Atomic Energy Authority.

First published 1983
Basil Blackwell Publisher Limited
108 Cowley Road
Oxford
OX4 1JF
and
The Association for Science Education
College Lane
Hatfield
Hertfordshire
AL10 9AA

ISBN 0 631 91010 7

Typesetting by Oxford Verbatim Limited
Printed in Great Britain

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Introduction

There are so many different sources of energy, discovered at different times, that it took centuries for scientists to recognise the underlying nature of the energy common to them all. Meanwhile, inventors and engineers discovered practical ways of using it by transforming some of the energy within common fuels into movement and, later, into electricity.

We have become dependent upon these useful forms of power in the home, in industry and for transport. The availability of energy, generated from fuels, affects our comfort, employment, communications, and national wealth. Now that the stocks of fossil fuels are beginning to run out we must all be concerned about the decisions being made for the future, including the possible hazards of nuclear power and the uncertain promise of alternative energy.

In the less developed countries there is a continuous demand for energy appropriate to other climates and life-styles, energy for the common amenities and for raising the standard of living.

1 Trying to Understand

WHAT IS ENERGY?

Energy resources of one kind or another are often in the news because they are essential for our way of living:

For our body warmth and activity

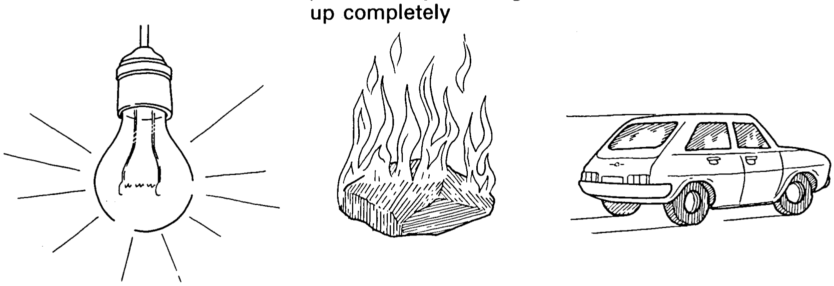
For the heating of our homes

In petrol and the fuels which run our traffic

To power our industry.

The important point about energy is that it can do useful work for us. Energy exists in many different forms, as heat, in fuels and food, as light from the sun, in electricity, in water and in nuclear materials. Coaxing useful work from these energy sources, is not always simple.

A calm warm sea contains plenty of energy but, if all the water is at the same temperature, we cannot use any of it. Daylight on a cloudy day is only a little better; plants can use a tiny proportion of this energy for photosynthesis to build up food or fuel, and it can slowly charge up the midget batteries that power a digital watch. Bright sunlight, high waves, falling water and strong wind are all more useful types of energy from which we can certainly extract work, given the right sort of technology, and at a price. The energy locked up in fuels is more valuable still. We can get intense heat by burning them, we can use them to drive cars and fly aeroplanes, and we generate electricity from them.



Each use approximately 360 thousand Joules.

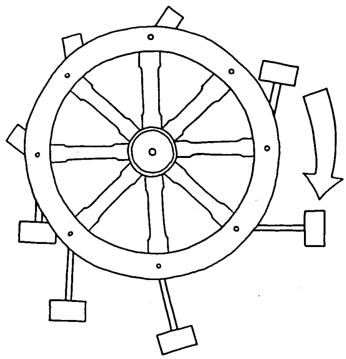
All energy, and the work it can produce, is measured in joules. A more familiar unit is the watt, used to measure power (that is, the rate of doing work). One watt is one joule of energy used every second.

THE EARLIEST MACHINES

Work has always needed to be done and the first sources of energy were people and animals. By the twelfth century windmills and waterwheels were in common use, but the idea of energy was still not understood.

Turning windmills are an impressive sight. Anyone who has seen around the inside of an old windmill with its huge wooden cog-wheels, often six feet or more in diameter, the massive central shaft made from a whole tree-trunk and the heavy grinding stones can imagine how marvellous such power must have seemed in the Middle Ages. Some early engineers became so fascinated by rotating machinery that they were led into the long and fruitless search for perpetual motion.

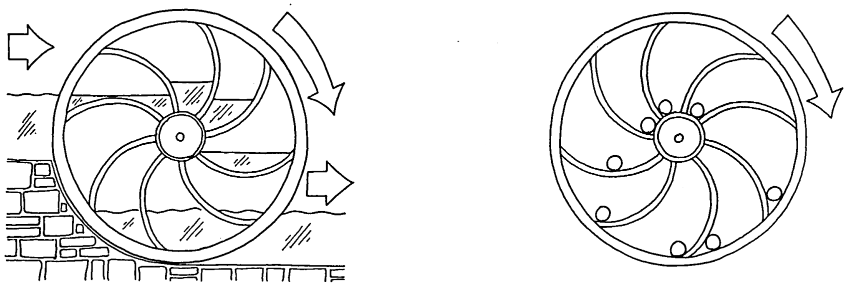
> Many a time have skilful workmen tried to contrive a wheel that shall turn of itself; here is a way to make such a one by means of an uneven number of mallets, or by quicksilver.
>
> *French architect of the thirteenth century.*



The mallet machine.

The connection between this device and the working waterwheel is obvious. There was often a close resemblance between actual machines and the plans for perpetual motion. They have in common an understanding of the driving power of descending weights and the consumption of this power as the weights rose up the other side. Could the first be greater than the second by arranging for the weights to have a greater turning effect on the way down?

Can you explain why the mallet machine would not work (without using any energy law)?



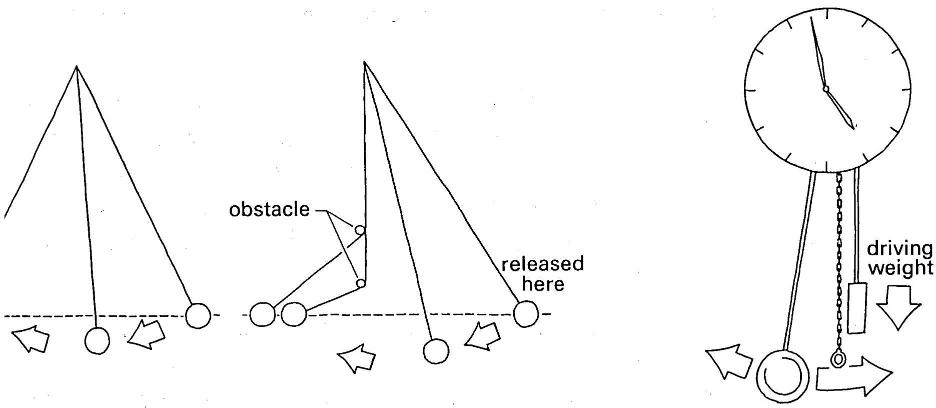
Left *The horn drum waterwheel.* Right *An early design for perpetual motion using heavy balls to turn the wheel.*

IS POWER INDESTRUCTIBLE?

At this time there was no scientific principle which could clearly state that this kind of perpetual motion machine, which would give us endless power, is quite impossible. Some inventors, like Leonardo da Vinci, had a mechanical instinct that such contraptions could never work. Even now, when the idea of energy is so much better understood, there are still hopeful and misguided inventors who take out patents for perpetual motion machines.

The earliest word for energy or power was 'vis viva' – living force – and this was applied to the moving of any weight, just as if power were alive, like working men and their beasts of burden.

One of the first experiments on energy was performed by Galileo. We find it reported in the *Two New Sciences*, a book written near the end of his long life when he was under house arrest, blind, and forbidden to publish any more scientific works. Years before, Galileo had studied the motion of pendulums in order to time his experiments on movement. He observed that the weight on the end of the string always rose to nearly the same height as that from which it had been first released, even if the string met an obstacle on the way: '. . . from this we can rightly infer', he wrote, 'that the ball in its descent, acquires a motion just sufficient to carry it back to the same height'.



Left *Galileo's experiment.* Right *Early pendulum clocks stimulated scientists to think about the driving power of weights.*

Try this simple experiment for yourself. Does it suggest that the power or energy of the ball is indestructible?

THE FIRST ENGINES

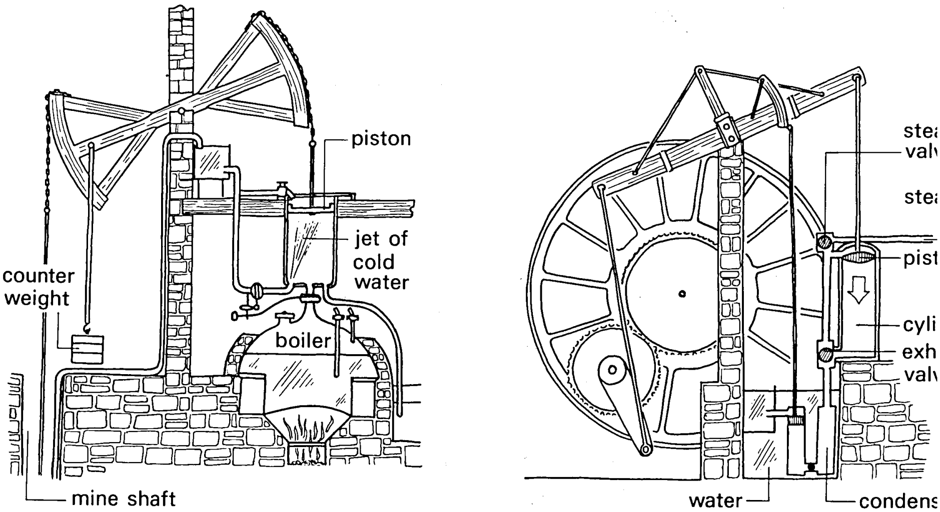
Another seventeenth century scientist, who took up Galileo's idea, was Christian Huygens in France. He was interested in how a slowly falling weight could operate a pendulum clock. He, too, believed that the energy (vis viva) of an object was not perpetual power, but was passed on to the pendulum and used for working the mechanism of the clock.

Huygens was probably the first inventor in this century to make a gunpowder engine with a piston and cylinder. The power of the explosion was strong enough to raise several men up into the air. It was little more than a spectacular toy; the next developments in engines were to have a practical purpose.

Flooding had always been a severe problem in mining. Pumps were sometimes operated by horses and occasionally by waterwheels, but it was common for miners to have to work all day knee-deep in water. Mines and galleries which could not be drained had to be abandoned. The first inventors of steam engines – Savory, Newcomen and Trevithick – were all mining engineers who designed their machines to pump out the mines.

You can see from the drawing of the Newcomen steam engine that it worked by the force of the steam pushing the piston up; a jet of cold water then condensed the steam, creating a partial vacuum so that atmospheric pressure would push the piston down again. Continual heating and cooling of the cylinder was wasteful of heat and the engine consumed large quantities of coal.

James Watt had worked as an instrument-maker at the university of Glasgow and had some knowledge of the science of heat. Nevertheless the improvement to the steam engine for which he is famous – the addition of a separate vessel in which to condense the steam – was a simple, practical idea. Why waste heat by cooling the whole cylinder?



Early steam engines: left *Newcomen engine (about 1712);* right *Watt's 'sun and planet' engine (about 1789).*

Engines improved ten-fold in performance during the following century. The 'duty' or efficiency was quoted simply as the quantity of water that could be pumped per bushel of coal burnt. In addition to

Watt's separate condenser the effort to wring more power from the fuel produced the following improvements:

Steam-jacketing the cylinder to conserve heat
Using high pressure steam (not possible until cylinders could be made strong enough to withstand it)
Using less steam and letting it expand more
Arranging for steam pressure to drive the piston down as well as up; converting the up and down motion into rotation whose speed could be controlled so that machinery could be harnessed to it.

How many of these improvements have also been used or suggested for the motor car engine?
Why is the steam engine not used in modern cars?

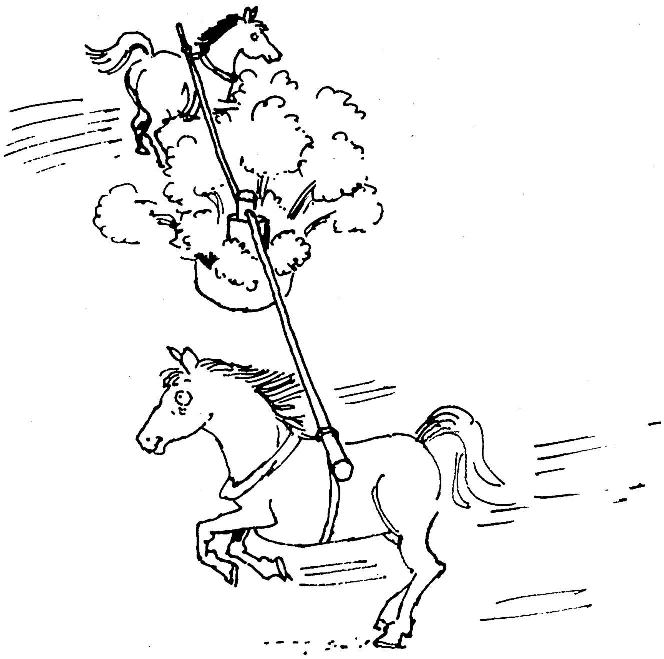
HEAT AND ELECTRICITY

The inventors of the famous 'Cornish engines' were not scientists and some, like Trevithick, had little education. They knew that heat could work machines, but neither they nor the scientists of the times could explain what heat was or why it powered the engines.

At the end of the eighteenth century a public experiment was carried out in Bavaria by Count Rumford, a professional soldier, who wanted to prove that heat was a kind of internal movement. He demonstrated to a watching crowd that the heat generated when he bored out a cannon was sufficient to boil half a gallon of cold water in less than half an hour. The boring instrument was turned by two horses, and these in turn, as he pointed out, were fuelled by quantities of hay.

A few years before this two Italian scientists, Volta and Galvani, had been investigating the curious twitching of a set of dissected frogs' legs which were hanging from iron wires by copper hooks. This was the incident which led Volta to construct the first ever electric battery (see *Technology* in this series).

In practice the electric current from such a battery turned out to be a marvellous source of experimental effects, especially in the hands of Michael Faraday. Not only did it generate heat, it could also produce



Heat must be a form of motion.

forces. Faraday had invented working prototypes of both the motor and the dynamo. In his mind electricity was a form of energy, as was a raised weight or a turning wheel.

To imaginative scientists it began to seem as if energy could exist in many different forms – movement, fuels, heat and electricity – and that any one of these kinds of energy could be changed into another.

A battery changes chemical energy into electrical energy.

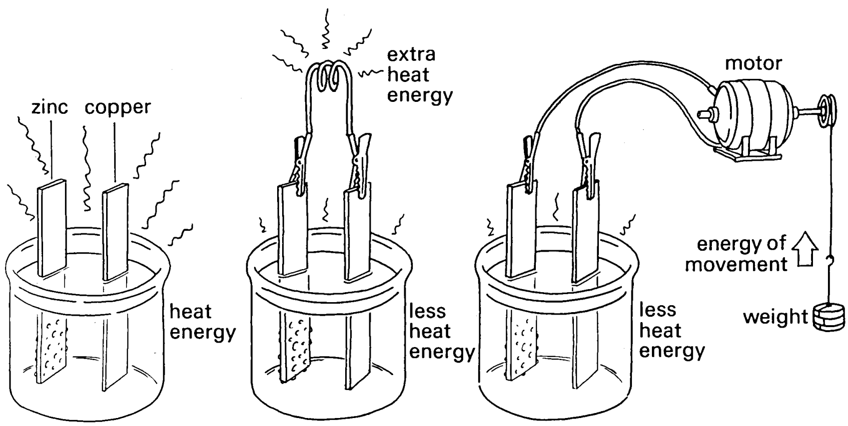
A motor changes electrical energy into energy of movement.

Friction between moving parts turns energy of movement into heat energy.

ENERGY CANNOT BE CREATED OR DESTROYED

In 1840 a British scientist, James Prescott Joule, carried out the first of a lifelong series of experiments designed to prove that the amount of energy – whether or not it had changed its form – always remained the same.

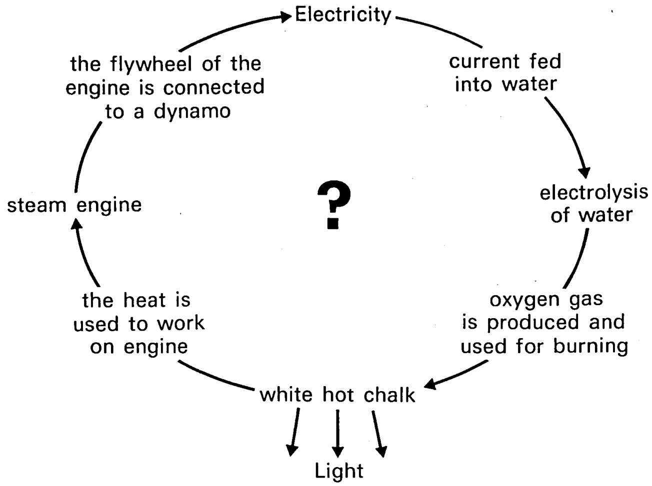
When zinc dissolves in acid it always gives off heat; if the battery is making current flow, less heat will be given off because some of it has turned into electrical energy. Joule's measurements showed that the amount of heat missing was exactly the same as that generated by electricity in the wires of the circuit. If the electricity was made to work a small motor then some energy of movement, which was measured, turned up in place of the heat.



Joule's experiment showing energy changing its form.

Finally the whole idea was put into a scientific law by a German doctor, Hermann von Helmholtz. First, he argued that you cannot get useful work without using up another form of energy. He reported that a speculator was trying to sell an idea to the public in which lighting was produced from a continuous cycle of energy changes in which no fuel was consumed. To a man of this industrial age the idea of getting light, or any form of energy, for nothing was unthinkable. 'Work is money', said Helmholtz.

Second, he argued as a doctor: 'The animal body does not differ from a steam engine; it requires nutrition just as much as an engine needs coal'. This was a new idea. If people and animals got their life energy from vegetation, which in turn gets it from the sun, then energy is the universal power that makes everything work.



Lighting power without using up energy? It's a fraud!

The scientific rule, now called the First Law of Thermodynamics, stated:

> The total amount of energy in the universe remains unchanged, *or* Energy cannot be created out of nothing, nor can it be destroyed.

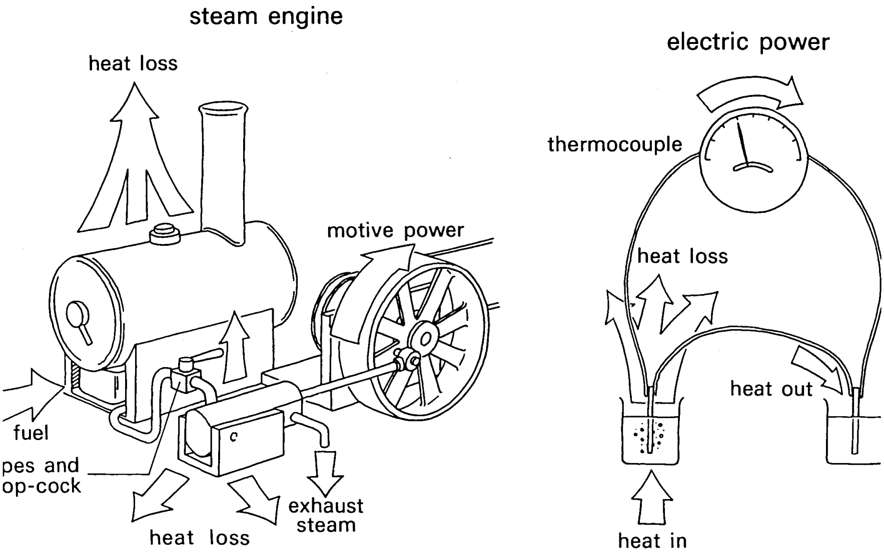
2 Useful Kinds of Energy

CHANGING HEAT INTO MOTIVE POWER

If it is true that the total of all forms of energy remains unchanged how is it that our stocks of energy are now said to be running out? What is this energy crisis?

The problem is that the most useful form of energy, power for movement, is not so easy to obtain from heat as heat is to obtain from movement. Think of yourself on a bicycle. You use the energy from food to get up speed. This gives energy of movement, but one squeeze on the brakes and all that energy turns into heat. The energy has not been destroyed, but can the heat be turned back into motive power?

Heat always tends to leak away and make the surroundings warmer. Unless it happens inside a well-insulated house it would be hard to think of a use for this low level energy. Steam engines can turn heat into motive power, but only some of it, and under the right conditions.



Left *Motive power into heat – easy, complete, rarely useful.* Right *Heat into motive power – difficult, incomplete, useful.*

If we look at a working model of a steam engine like the one illustrated it is not difficult to see where heat leaks away. A lot escapes round the boiler and the hot pipes. How could this be reduced? Does this happen in a car?

Spent steam and hot water are exhausted from the cylinder at each stroke.
Could this outlet be blocked up?
Would the engine still work?

These two problems are general. Even if an engine were perfectly constructed with no friction in its bearings and lagging around all its hot parts it still could not convert all the heat given to it into motive power. Some heat is always discharged to the atmosphere or into a special cooling system. The overall efficiency of an engine cannot be one hundred per cent.

Now look at a thermocouple like the one illustrated which turns heat into electricity, another form of motive power. The same problems arise again:

Some heat escapes from the thermocouple.
Heat is taken in at the hot junction but some is rejected at the cold junction.
Try keeping both junctions hot. What happens?

The greater the temperature difference between the junctions the greater is the current produced. The same kind of thing happens with all engines and turbines. The hotter the engine is inside the more the heat that turns into motive power. This makes it worthwhile to use superheated steam at high temperatures in power stations. In practice no engine yet reaches the efficiency of which it is capable, but they are improving.

Cart horse	> 1% efficiency (approximate)
Newcomen steam engine	2%
Steam engine of the 1880s	17%
Internal combustion – petrol	25%
engine diesel	35%
Steam turbine operating at 600°C	40%

It is impossible to turn heat completely into motive power (Second Law of Thermodynamics).

The use of electricity developed slowly. The first public power station was built in the 1880s but for fifty years the main use of electricity was for lighting. Its growth was hampered by legislation designed to protect the coal industry from competition. Not until the First World War did it prove its value to industry. The ease with which such power could be transmitted made it ideal for small firms in scattered locations. The Central Electricity Generating Board was set up in 1926, the national grid followed soon after and there was a nationwide boom in the use of electric power.

As early as 1894 a hydroelectric power station was set up at Niagara to turn the motive power of running water into electricity. It seemed at first as if the dynamo or alternator was the natural successor to the old waterwheel. Fifty years ago the most advanced nations in the world, judged by their use of electricity, were Norway, Canada and Switzerland. Sweden still gets eighty per cent of its power from hydroelectricity.

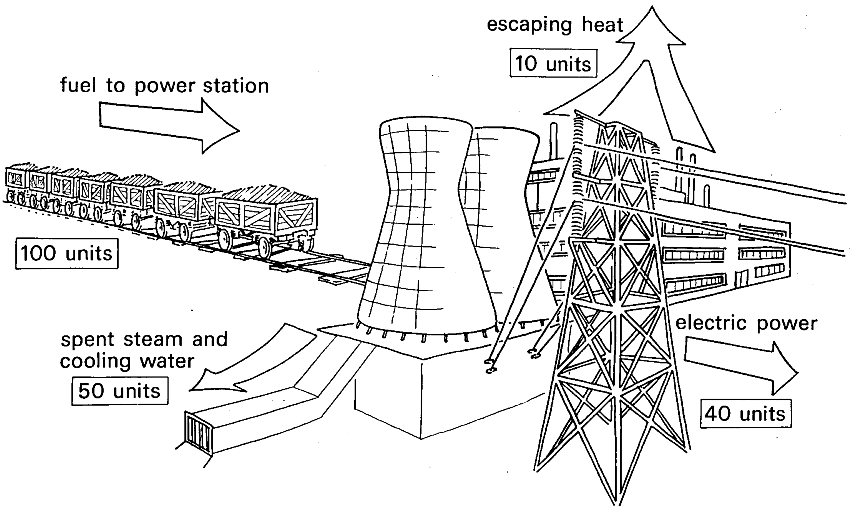
Nowadays the power that turns the dynamo and generates our electricity in the power station is more often from a turbine working on steam raised by the burning of some fuel.

Fuels used to generate electricity (UK 1981)

	Coal	Oil	Nuclear	Hydroelectric	Total
%	79.6	7.3	11.2	1.9	100

What we have learned about working efficiencies also applies to a power station. By burning fossil fuels and heating the steam from the boiler up to 500–600°C along with pressures as great as 300 atmospheres it is possible to reach efficiencies of nearly forty per cent. This still means that over half the energy in the steam is wasted and more will be lost from the dynamo and electrical cables.

This pattern is common to all kinds of electricity generating stations; more than half of the energy in the fuel, coal oil or nuclear material, is carried away in the cooling water. It is wasteful but inevitable. Several ways have been tried of using the energy in this warm water – central heating for neighbouring housing, warmth for greenhouses to increase the production of tomatoes or other crops, raising the temperature of a river or lake for hatching trout commercially.



Generating electricity from fuel in a power station.

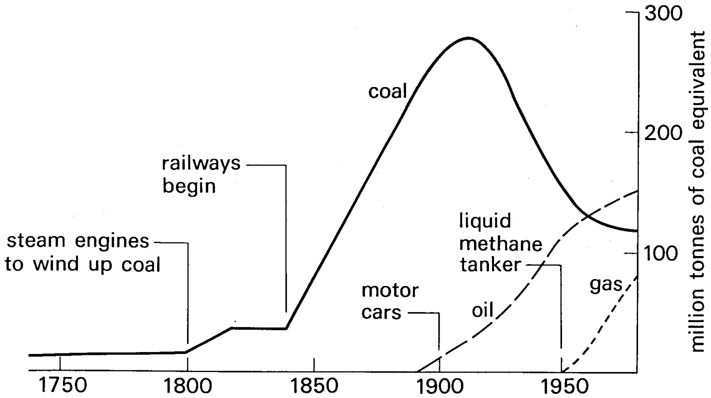
Do people like living near a power station?

THE USE OF COAL

Coalmining is not an outdated activity and produces an increasing proportion of Britain's electric power. Britain still has great reserves of coal, and is developing new techniques for exploiting narrow veins by automatic machinery and new methods of pulverising coal so that it can be used almost like a liquid, which greatly increases its burning efficiency.

The coalmining industry is faced with problems. In the past the death-rate among miners from pit accidents and silicosis (damage to lungs resulting in a lingering death in middle age) used to be appalling. Conditions have improved but it still remains one of the most hazardous industrial occupations. The burning of coal contributes to air pollution by producing sulphur dioxide and 'acid rain'. This is a health risk to the general population.

Our attitude towards the environment produces another problem for the coal industry. Pithead tips and opencast mining are eyesores and hazards that local communities are unwilling to tolerate. In 1963 a coal



A graph to show the decrease in the use of coal in the last 40 years in Britain.

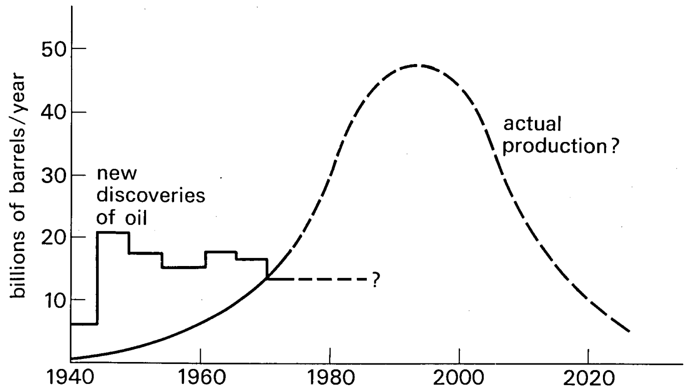
tip in Aberfan, South Wales, slid down the hillside demolishing several houses and a school, killing over a hundred children. The National Coal Board is now forced to ensure the safety of such tips and landscape disused mining sites. There is often vigorous and understandable local opposition to new mining works in regions of scenic beauty.

Imagine such a situation and examine the conflicting points of view of local residents: employed, unemployed, shopkeepers, farmers, ramblers' organisations, the Department of Energy and the National Coal Board. What would you decide?

OIL AND NATURAL GAS

Petroleum oil, like electricity, was first used for lighting and also for small cooking stoves. The coming of the motor car changed all that. Now it is valued for its liquid 'fractions' – petrol, diesel and heating oils, lubricating oils, chemicals for plastics, and bitumen. Quite apart from this richness in its composition, it has an advantage over coal in that it can be transported by pipeline. Forty years ago the USA was the prime producer of the world's petroleum but now the focus of the oil industry has moved to the Middle East which alone produces almost half the total output. This fact has influenced world politics to a remarkable extent.

The world's stocks of petroleum cannot last for ever. New discoveries have been made under the sea and within the Arctic Circle. There are deposits of oil-bearing shales but these would be expensive to work. The question to which everyone wants to know the answer is: When will the oil run out?

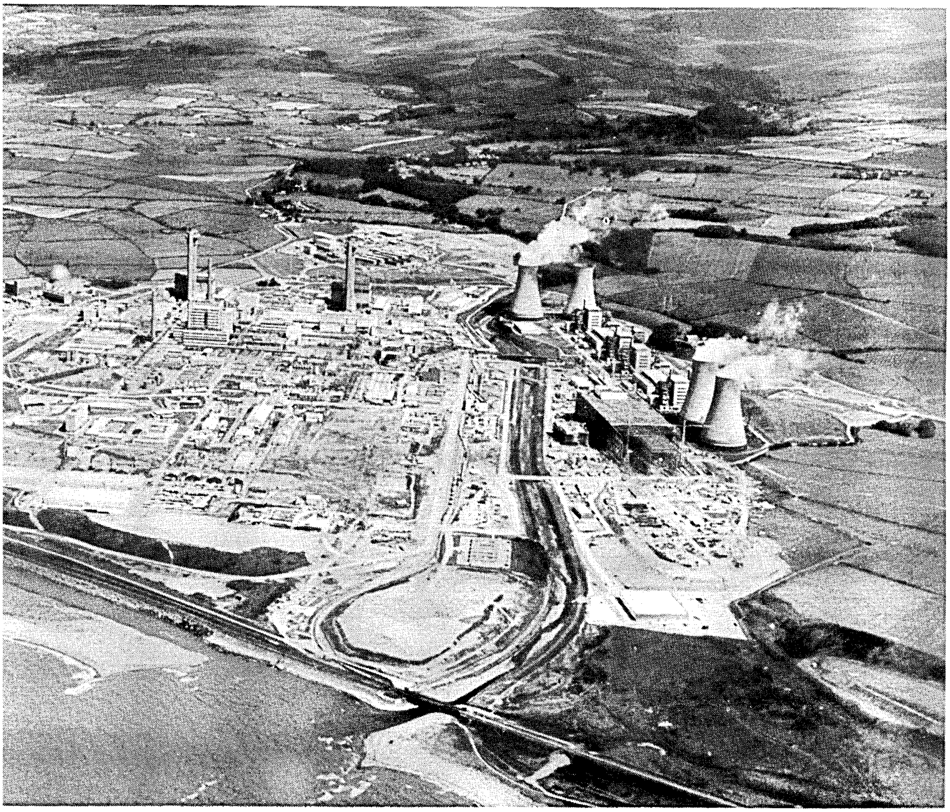


Guessing the future for oil.

What the graph shows most clearly is that the rate at which oil is being produced now outstrips the rate of discovery of new fields. It is expected that production will reach its peak about the year 2000. This forecast, together with the continual rise in price, is beginning to curb its use and our government is not planning to build more oil- or gas-fired power stations. In one year, 1973, the cost of oil more than doubled, but this was due not so much to rising costs of production and prospecting as to a deliberate policy on the part of the oil-producing countries, OPEC, to increase their revenue and make existing stocks last as long as possible. This had an immediate effect on the demand for oil and may have been responsible for the beginning of the great recession in world trade. The fixing of oil prices by the OPEC countries is a debate with worldwide importance.

The conventional nuclear power process

Almost all Britain's nuclear power (eleven per cent of the electricity) comes from this kind of station, the first of which was Calder Hall, built in 1956.

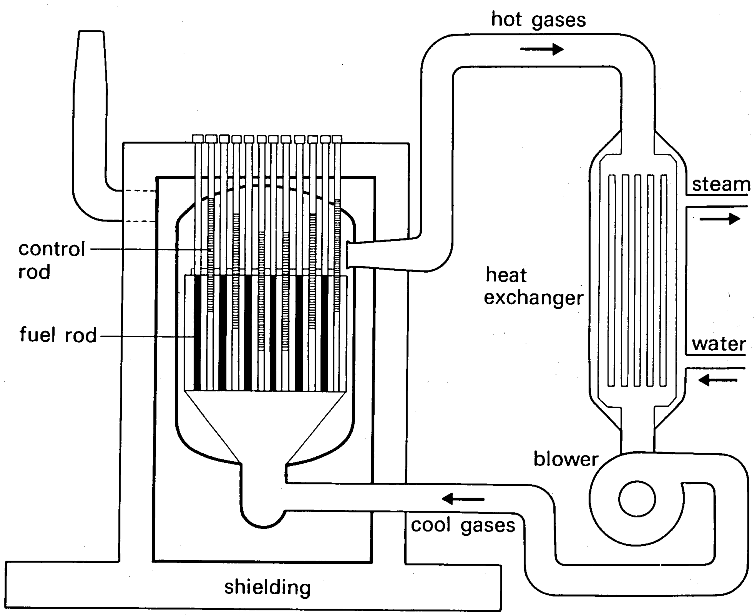


An aerial view of the Sellafield works of British Nuclear Fuels Limited in Cumbria. Calder Hall nuclear power station is shown on the right. Sellafield works is the UK centre for the reprocessing of irradiated fuel from which by-product plutonium and unused uranium are extracted for future use.

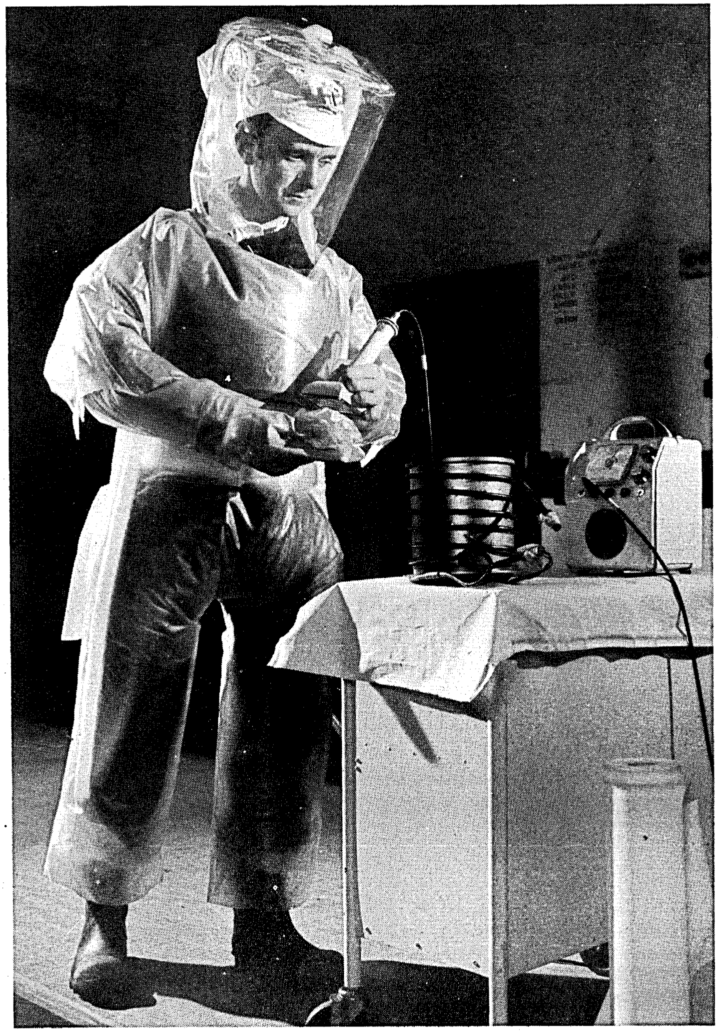
The fuel is sometimes natural uranium containing U^{238} and only one per cent of the fissionable isotope of uranium – U^{235}. In other reactors this fuel is enriched by increasing the proportion of U^{235}. Most reactors are gas-cooled. Carbon dioxide is blown through the heart of the reactor to take away the heat in order to use it to raise steam. The chain reaction, by which the neutrons from one exploding atom of U^{235} hit others, works best if these neutrons are slowed down by a 'moderator'. Graphite, a form of carbon, is used.

The reaction is controlled by rods of boron or cadmium which can be lowered into the reactor to absorb the neutrons. This damps down the reactor and the addition of boron powder can stop the reactor altogether.

After a few years the original fuel is spent. A large proportion of the U^{235} has been used up and the fuel rods must be removed and replaced by fresh ones. The spent fuel rods are highly radioactive. The fission-able uranium has broken down into various other atoms of less weight which give off harmful radiation. The rods are lowered into tanks of water by remote control and left for a few months until some of the short-lived atoms lose their power. The remaining material, still hot with radiation, contains some valuable plutonium (made from the commoner isotope U^{238}), and the rest is waste which will be dangerously radioactive for nearly a thousand years.



A schematic diagram of the reactor at Calder Hall. The fuel rods are natural uranium in a graphite moderator. The coolant is carbon dioxide. The generating capacity is 70,000 kilowatts.

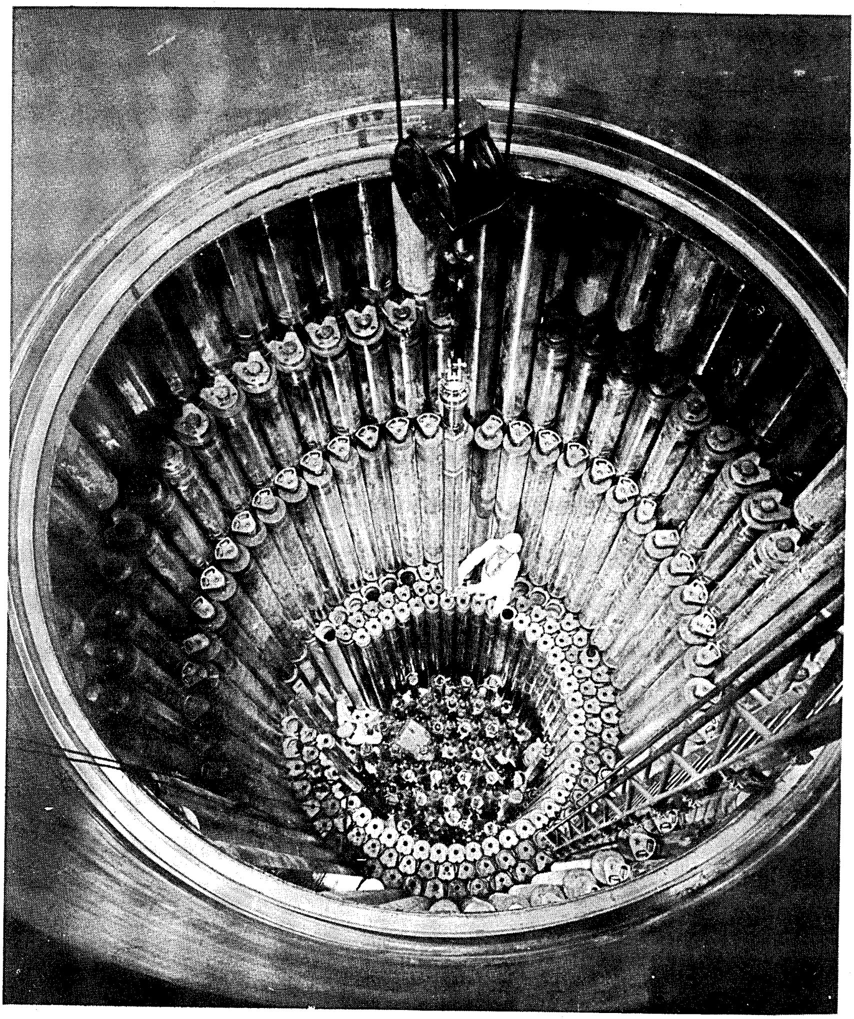


A technician in a nuclear power station wearing a radiation protection suit.

The plutonium in the waste material is valuable because it, like U^{235}, is fissionable. Indeed it gives off more energy than the uranium when it splits up. It is reasonably easy to separate from other material in the nuclear wastes. This makes it valuable for nuclear weapons. The first nuclear power station in Britain was originally built to make material for bombs. Extracting plutonium is done at Windscale (Sellafield). The plutonium can be used to fuel another type of power station – the fast breeder reactor.

The fast-breeder reactor

The core of this reactor is almost pure plutonium which is surrounded by natural uranium or thorium. No moderator is used so fast neutrons hit the uranium and change much of the common U^{238} (which is not itself fissionable) into more plutonium. In this way it breeds more plutonium than it uses.



A view from above the reactor at Dounreay showing the arrangement of the plutonium fuel rods.

This kind of plant is far more efficient than the conventional kind. It can make available up to seventy-five per cent of the energy in uranium or thorium instead of using the fraction which is present only in the fissionable form. It would enable limited resources of these materials to last much longer, perhaps thousands of years instead of fifty, which is the forecast if the conventional kind of nuclear power station is used.

So much heat is generated in the fast-breeder reactor that only the best conductor of heat, liquid sodium, can be used to carry it away.

At present Britain's only fast-breeder reactor is a small prototype power station at Dounreay in the north of Scotland.

SHOULD WE HAVE MORE NUCLEAR POWER?

The heart of the nuclear debate is whether these reactors, the reprocessing plants and the systems for storing and disposing of waste, are safe and necessary. Those in favour of the industry say that they are, those against say that they are not. Anxiety about the safety of nuclear power has risen to such a pitch that public action groups now campaign against it in many countries. In Austria, where a national referendum was held on the question of building nuclear power stations, a clear answer of no was returned. The argument centres around the following points:

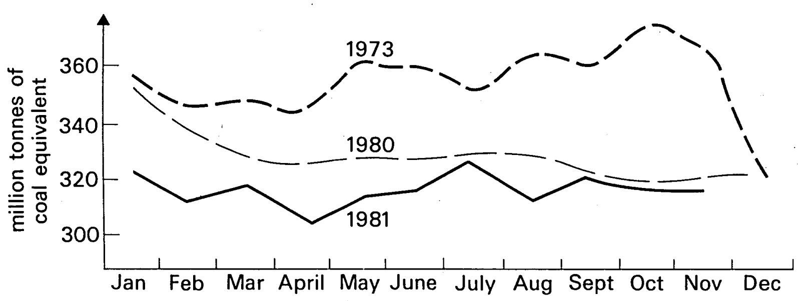
A major accident in a nuclear power station would be horrific. If the worst happened and it blew up, lethal radioactive material would be blown far and wide. Such an event seems improbable, although not impossible as the near-miss at Three Mile Island, USA, in 1979 showed.

A minor leakage of radiation, for example contaminated cooling water or steam, is a much more probable risk and has already occurred on more than one occasion. So far it has never been serious enough to be an immediate health hazard but it is argued that it could build up to higher levels by concentration in certain food chains. It might then be serious enough to increase the risk of cancer or genetic damage. Those most at risk would be the workers in the power stations, the uranium miners and those living near a power station.

How are the 'hot' radioactive wastes to be disposed of? The latest answer is to fuse them into a glassy material which might then be stored or buried in a geological fault in the Earth. The Atomic Energy Commission is currently exploring sites but so great is the concern and fear that nine out of ten local councils approached have refused permission even for a preliminary survey. Alternatively they could be dumped in deep parts of the ocean.

The last decade has seen an escalation in international terrorist groups who are always on the lookout for weapons. Plutonium, especially if it has already been extracted from the spent nuclear fuel for use in a fast-breeder reactor, is the raw material for nuclear bombs. Many countries have signed Non-Proliferation treaties in an attempt to curb the spread of nuclear weapons but this becomes increasingly difficult when world production of plutonium in power stations increases. There have already been incidents in which plutonium was found to have disappeared. What sort of police action or army presence might be necessary to prevent the stealing of plutonium, even a piece no bigger than an orange?

Do we really need more electric power at all? During the 1950s and 1960s the answer was definitely yes. Every year there was an increase in energy consumption. Oil was cheap, and the rise in living standards at home (central heating) and growth in the manufacturing industries were gobbling up power. It was a race to keep up with the demand, so more and more power stations were built. Then, from 1973–74, the price of oil trebled, everyone tried to economise, and the government introduced a 'Save It' campaign. The result was that the demand for energy dropped so much that there is now more than enough capacity in the electrical generating system to supply all our present needs.



Total consumption of energy (UK).

Some argue that nuclear power is the cheapest way to make electricity. Others stress the need to be independent of the politics of the OPEC countries after our North Sea gas is used up. The world's reserves of fossil fuels – oil, gas and coal – cannot last for ever, so what of the future?

Estimated lasting time at present rate of use

oil	30 years	
gas	50 years	
coal	300 years	
uranium	50 years	(conventional use)
uranium	2000 years	(fast-breeder reactors)

These estimates could prove wrong by fifty per cent or more if rich new deposits are found, but the fuels will inevitably run out. To some people this is a clear indication that we should invest in fast-breeder nuclear reactors now.

3 How Energy Affects our Living

THE USES OF ENERGY IN BRITAIN

To understand the part that energy plays in the life of the nation, we must compare the uses made of the common power sources.

Energy uses in 1980 by percentages

	coal, coke etc	liquid fuel, oil, petrol	gas	electricity	total
domestic	5.9 −	1.9 −	14.9 +	4.7	27.4
industry	6.4	12.5 −	10.7 +	4.8	34.4
transport	0	24.7 +	0	0.2	24.9
other (agriculture and public offices)	1.1	5.2	3.7	3.3	13.3
Totals	13.4	44.3	29.3	13.0	100

\+ increasing
− decreasing

There are some hidden features in the table. Coal is more important than appears at first sight since nearly eighty per cent of our electricity is generated from it. Some of the energy used in industry, perhaps ten to twenty per cent, is used for the comfort of the workers rather than for industrial processes. The same is true of schools, offices and homes.

Consider the increasing and decreasing items on the table and give reasons why they are changing.

IN THE HOME

Energy is used at relatively low levels for heating, and it is here that economies can most easily be made. Various methods of house insulation are recommended: if houses were specially constructed for economy of energy the savings could be greater still. The Centre for Alternative Technology at Machynlleth in North Wales has built a special 'conservation house'. It has small double-glazed and deep set windows, extra thick (fibre filled) walls and a small inlet flue in the roof for the combined heat and ventilation system. This is driven by a small 150 watt pump and the total heating required is only about 20% of that needed in a normal, well insulated house. On the debit side the building costs are considerably higher and the free choice of house design has been severely limited.

Should the government make some of these energy-saving features compulsory in all new building?

Other suggestions for economising on the domestic consumption of energy include solar heating panels (page 36), and district heating or local generation of combined heat and power (page 34). A lot depends upon the temperature at which we set our heating. Even such personal habits as use of lighting, fashions in clothes, and disposal of rubbish, can alter the amount of extra energy we need.

Would you be willing to sort your household rubbish for combustible material, or to make compost, if you could convert the energy to light and heat for the house? Would you be willing to get up at sunrise and go to bed soon after sunset to avoid the need for artificial light?

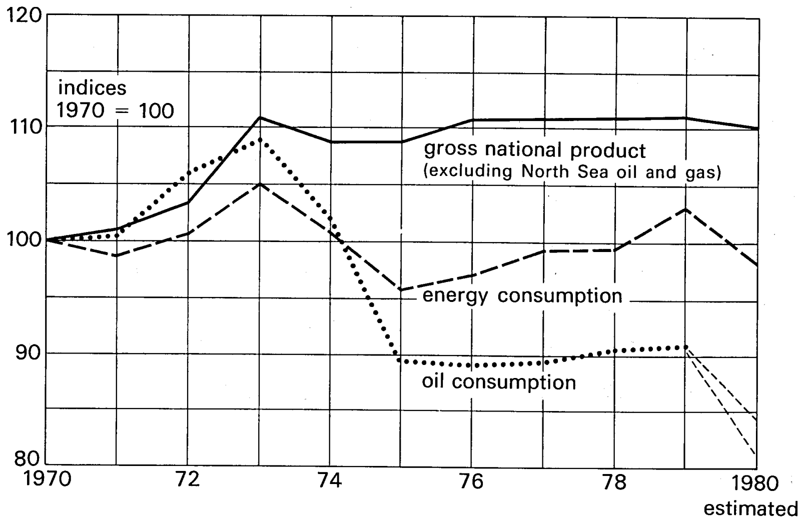
INDUSTRY

A manufacturing country such as Britain uses a large proportion of its energy output for industry, but it does not follow that there is a close connection between manufacturing output (and hence the wealth of the country) and the amount of fuel used.

In 1978 the British steel industry used thirty-nine per cent of industrial energy; two years later the figure was fifteen per cent. Several large steel works had closed down due to the economic recession but the more modern works, using more economic energy processes, had survived. Twenty years ago it needed 1½ tonnes of best coal to produce 1 tonne of steel, but this has decreased considerably. Other metals, although produced in smaller quantities, may be even more expensive in fuel; aluminium takes five times as much as steel. The manufacture of chemicals and building materials are also energy-intensive.

The chemical industry is in a special position since the products of petroleum oil are often their raw materials as well as their fuel. About twenty per cent of the oil and a smaller proportion of the gas, which is used in industry is 'feedstock' for the production of plastics and other useful chemicals.

Fast-growing industries such as microelectronics and computers do not consume large quantities of power. They depend much more upon detailed work and technical skill. This makes a great contrast with the vast coal-eating steam engines of the early Industrial Revolution.

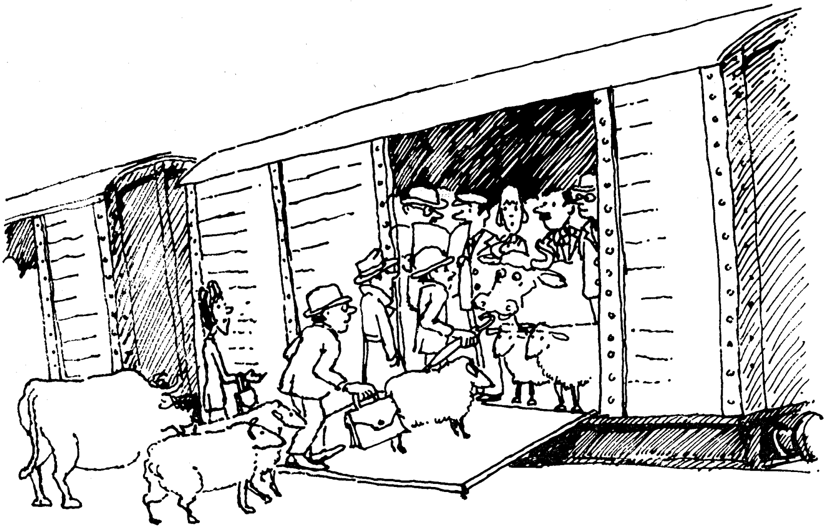


Relative economic growth and energy/oil consumption 1970–80.

This graph gives information about the effect of the oil crisis of 1973 on Britain. What does it say about Britain's dependence on oil?

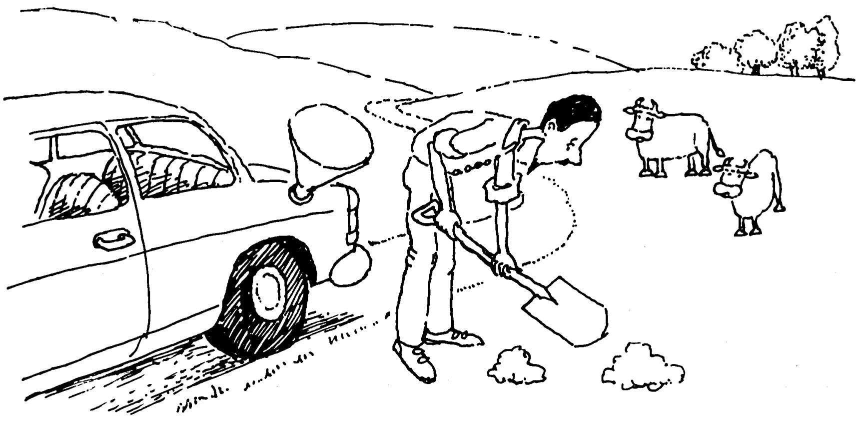
This is an increasingly large user of the petrol and diesel fuel that we get from oil. Part of the problem is that we choose the car, a form of travel which gives speed and privacy but is expensive in terms of fuel when compared with mass-transport systems.

Private cars with one or two passengers use much more petrol per head than well-loaded buses and trains. The same is true of the transport of goods: it is cheaper in fuel to send materials as part of the load of a train than to use heavy lorries. The cost of an air journey in energy per passenger per mile is about three times that of a private car and seven times that of a bus. Are there solutions to the problems caused by our choice of speed with privacy?



Switch people or goods to shared-transport systems?

Research is going on to develop new types of engine using different fuels with better economy. Three examples of this are the Sterling steam engine, the gas turbine engine and the electrical storage engine. None are yet in common use.



Develop and use other fuels for powering vehicles?

Our preferences in transport seem to go against moves to economise on fuel. They also produce traffic problems. Consider the transport in your neighbourhood – cars, buses, bicycles and trains – and decide what action, if any, you would like the local authorities to take in order to improve economy and make life more pleasant and safer.

4 Our Energy Future

WHAT CAN BE DONE?

Existing stocks of fossil fuels are running out. They are non-renewable. All were formed from living organisms which acquired their energy from the sun by photosynthesis. This process still goes on; low-grade fuels such as wood and peat are being formed, but not at a rate which could replenish our stocks. We need to consider what actions can or should be taken now to safeguard our standard of living for the future.

Should we rely on a careful policy of low energy consumption, economising on the use of fuels in all possible ways? The government could bring in regulations to ensure that houses and flats are well-insulated and provided with solar heating panels. This would be bound to make homes more expensive in the short run. We could design power stations so that they provided local towns with heat from their waste; this would be more effective for groups of dwellings than isolated houses. It may be possible to transport waste hot water by pipeline to neighbourhoods at some distance from the power station. Small groups of houses might economise by generating their own heat and power.

Should we build more fast-breeder nuclear power stations? The arguments for and against this are presented earlier in this book.

Coal will last much longer than the other fossil fuels. Should we try to exploit our coal in new ways? Burning coal pollutes the atmosphere and is responsible for more deaths than either gas or nuclear power. It may prove possible to 'gassify' it underground, purify it, and transport it by pipeline to homes and factories. We need to explore the methods by which it can be turned into a liquid fuel to run our cars and trucks, as is done in South Africa.

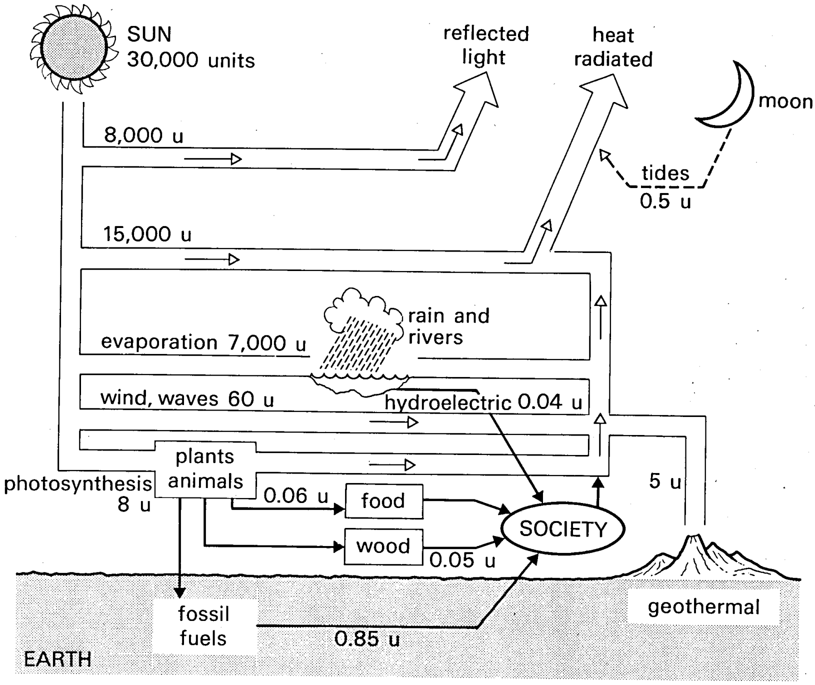
Could we use fusion power? This is the way the sun and the stars generate their enormous heat. The fuel might be heavy hydrogen which exists in large quantities in our oceans, but other rarer elements such as lithium would be needed. The hydrogen bomb uses fusion to produce its vast destructive power but making continuous controlled power in this way has not proved easy. After more than thirty years of international research the breakthrough is still far away.

Can we develop new technologies to use the renewable supplies of energy that come to us by the action of the sun, the tides, and the heat inside the earth?

SOLAR ENERGY

Energy in the form of light and heat floods in to us at a rate of about 1.4 kilowatts per square metre of our atmosphere. Much is absorbed or reflected before it reaches the surface of the Earth. There is plenty left but it is not easy to use and harness. We need high temperatures and pressures to get efficient conversion of heat into motive power or electricity. At present, only one part in 30,000 of the sun's direct energy benefits the world's human societies.

The intense radiation of the sun above our atmosphere is only used directly by the solar batteries of satellites and space craft. It has been proposed that special satellites might be launched, packed with such



. . . and only one unit to society.

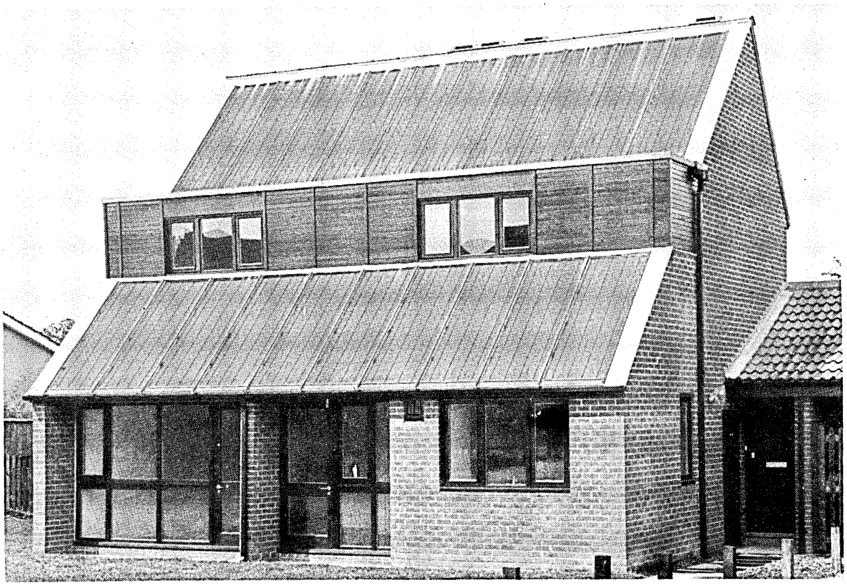
cells, to generate large quantities of electricity; the problem is to get it back to Earth. A powerful beam of microwaves has been suggested for this purpose, but the results of misdirecting such a beam might be devastating. It is expensive; the latest American estimate for launching a fleet of power satellites was three thousand billion dollars.

Solar cells for use on Earth are still too expensive to be economic for any but the smallest tasks (digital watches, calculators).

In hot countries which have clear skies it should be possible to focus solar radiation, by means of mirrors, onto a boiler to raise steam for the generation of electricity in much the same way as fossil fuels do for us now. The USA and France have pilot schemes that work in this way but there are technical problems to be overcome.

Because of the British weather solar power stations are not an option, but although we may not be able to generate electricity from the sun we can use its heat directly in our homes. To do this we have to construct solar panels through which water is pumped either for direct use in central heating or indirectly for warming the water in the hot tank.

The panels can be used on any sort of house but they are more effective if it has good insulation. Early panels were efficient up to about 21°C,



A solar house in Milton Keynes, Buckinghamshire. The solar panels cover the especially large surface area of the roof. The house is also very well insulated.

but new materials have been developed which will reach temperatures as high as 65°C. Even so, additional heat will always be required on cold and cloudy days.

WIND AND WAVE POWER

These energy sources are not only renewable, they are also second-hand versions of solar energy. They are formed by the sun's driving power on the atmospheric machine. Both have been used since ancient times for grinding corn, pumping water and other simple mechanical tasks. Now we would like to be able to use them to generate electricity in order to save our dwindling resources of fossil fuels.

The Lassithi plain in Crete: thousands of windmills cover the plain.

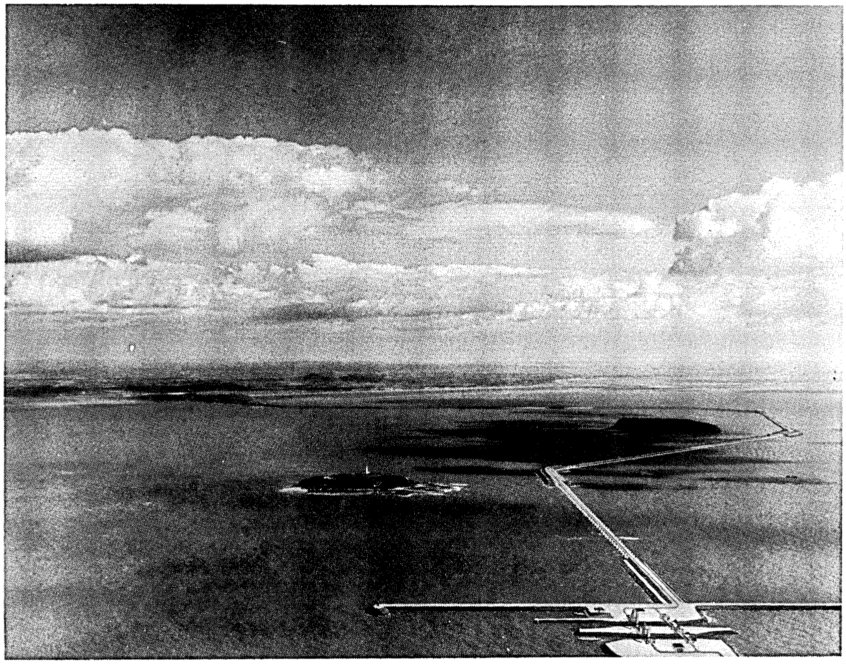
Because air is such a thin material, even high-speed winds contain relatively little power. Wind turbines would have to be built on exposed sites, they would have to be large as well as light, and be able to be swung round to face into the wind. Some on towers 200 m high have been designed in America, and in Britain it has been suggested that huge versions might be constructed out at sea in shallow coastal waters.

Installation costs would be high, but there is another problem. The continual buffeting by high winds might so shorten their working life as not even to repay the energy used in their manufacture.

Wave power seems to be a promising option for Britain; there is a great store of energy in the breakers that beat upon our western shores. Research has been going on and huge floating 'ducks' have been designed which will be rocked by the waves and enable their energy to be converted into electricity. Suggested sites for great rafts of these machines are western Ireland or the Shetland Isles. The technology is not fully developed and it will be necessary to wait to see if it can be successful at a competitive price. As fuel prices rise, some alternative sources of energy may become more inviting and desirable.

Tidal energy

There are few places where the difference in heights of the tides is great enough to be an effective source of power, but one is the Severn estuary. The illustration shows a photographic simulation of the proposed 'two-basin barrage' stretching from Cardiff to Weston-super-Mare. Its output could be equal to that of one or two large power stations (about three per cent of Britain's total electricity) but the initial expense would be enormous.



The Severn barrage: a photographic simulation showing an aerial view of the inner barrage from near Lavernock Point, looking towards Bridgwater Bay.

The environmental effects would be considerable. Whenever the subject comes up for discussion there are objections from those who fish in the estuary, the conservationists, and those concerned with the holiday industries on both coastlines.

GEOTHERMAL ENERGY

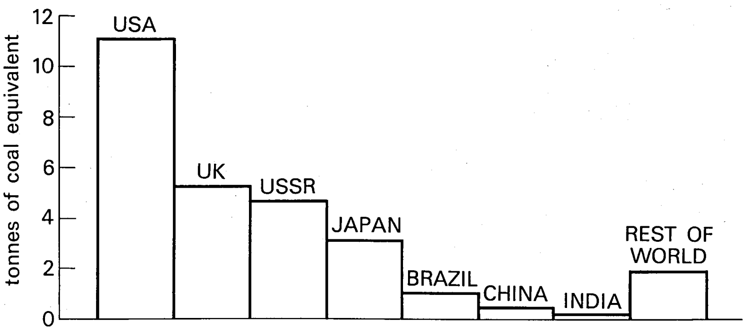
There is a tremendous store of heat inside the Earth which leaks out slowly through the crust with little benefit to anyone. The deeper below the surface the higher the temperature, but in some places heat emerges as geysers or hot water springs. Countries such as New Zealand and Iceland have geysers supplying hot water which they can use for local central heating. In some places – Italy, New Zealand and California – geothermal energy is used to raise heat in power stations which generate electricity.

In Britain there are some hot springs in Bath, and research is going ahead in other parts of the West Country to find out if useful sources of energy can be tapped by boring holes into hot areas and pumping water through to extract the heat.

5 Energy for the Less Developed Countries

WORLD USE OF ENERGY

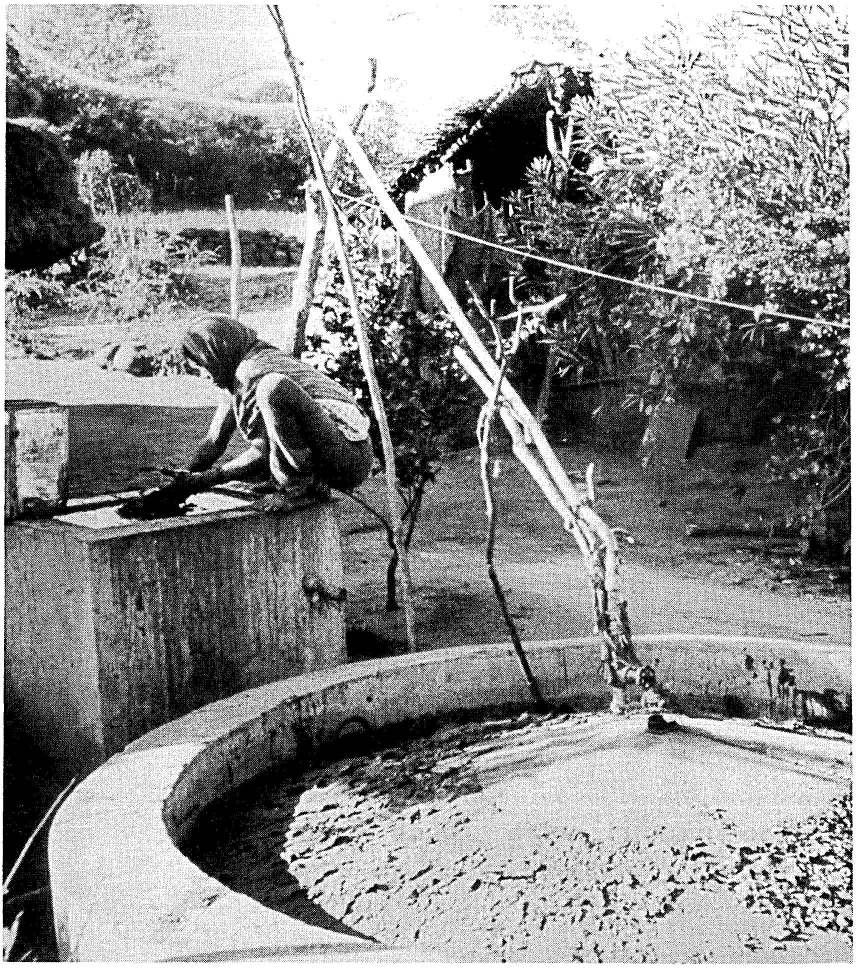
The people of less developed countries, which include about two-thirds of the world's population, use little energy. There are several reasons for this – low standard of living, poverty, the high price of oil, a non-industrial economy. This does not mean that they do not need more energy but their needs may be different from ours and the possible solutions may also be different.



Annual energy consumption per head of population.

COOKING AND HOME LIGHTING

The most obvious material is locally collected wood for fires, but there are many places where wood is getting increasingly difficult to find. In large areas of Africa the land is too dry for much woodland, and in parts of India and elsewhere the pressure of population and agriculture makes wood scarce. A common substitute is dried animal dung, which the women mould into cakes and dry in the sun. Not only does this encourage flies and disease, it also deprives the land of essential natural fertiliser.

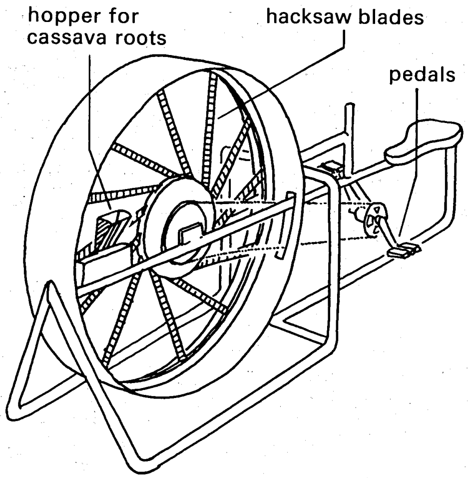


The woman is pushing dung into a methane generator in India.

It is more useful to let human and animal dung ferment with water in closed containers so that it liberates methane (natural gas). This can be used for cooking and lighting, while the water slurry which is left turns into ready-to-use fertiliser within a few weeks. Such 'biogas' techniques have the added advantage of producing better village sanitation. In India, methane generators, although still comparatively rare, have increased tenfold over the last few years.

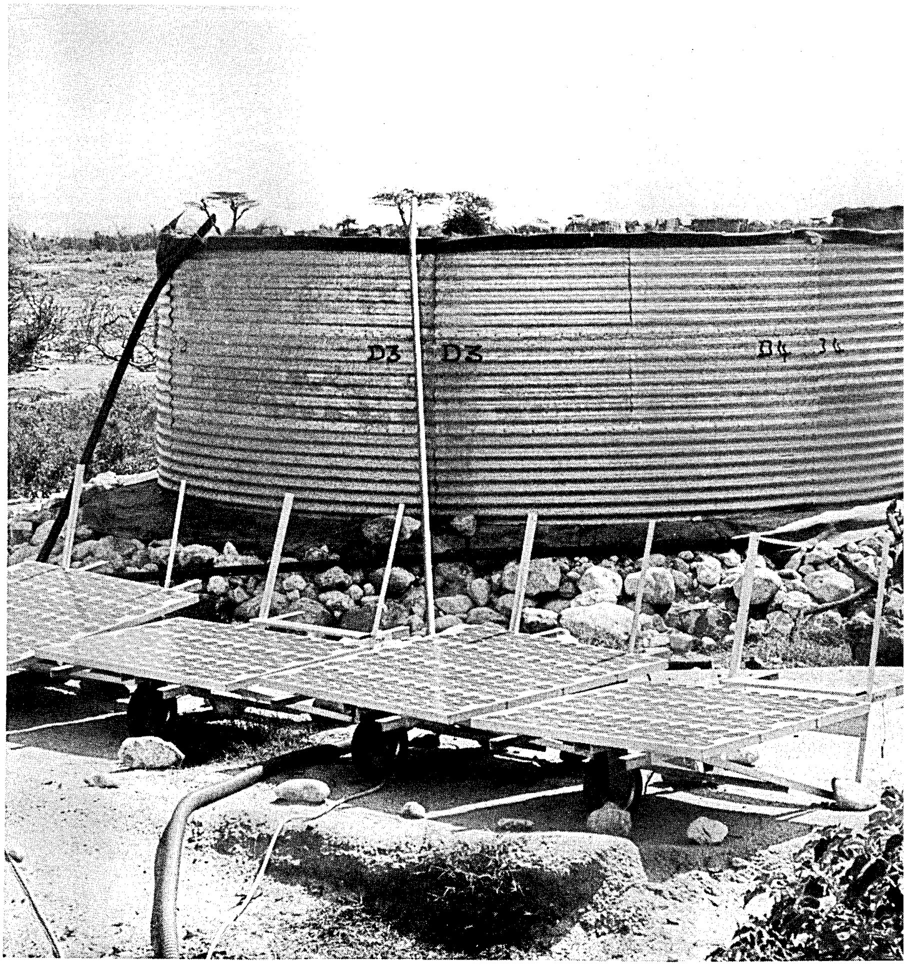
Most villages run some processes which need energy. They may want to produce cloth, make or mend small pieces of farm equipment, or process their food products. In the past, small industries have depended upon power from diesel engines, but rising fuel prices are making this too expensive. Surplus methane from the biogas process could perhaps be used as an alternative fuel.

The future of village industry depends on the appropriate intermediate technology which uses simple local resources in an imaginative way.



A grinder for the tropical plant, cassava.

Agriculture requires energy of two different sorts. Routine tasks such as ploughing, irrigating, reaping and grinding depend upon human, animal, wind or solar power. The last three have special advantages for special cases. Tractors which are so commonly used in farming in developed countries have severe disadvantages – they consume expensive fuel and require expensive spares.



Solar panels for pumping water in Africa.

Agriculture depends upon the use of fertilisers. In the developed countries, artificial nitrogenous fertiliser is manufactured from nitrogen in the air, but this is an energy-expensive process not usually available in the less developed countries. Perhaps it may be possible to raise more plants which are themselves bearers of the bacteria which 'fix' atmospheric nitrogen for use on the land. Meanwhile, agriculture in the less developed countries which seems much less efficient, uses less energy and actually produces more energy in its food for the energy input than does mechanised farming. Our agriculture is lavish in its use of energy.

food energy output	:	*energy input*
10	:	1 – unmechanised
1	:	3 – mechanised

It takes a great deal of extra energy to make a real increase in food production by mechanised farming.

TRANSPORT

Motor fuel is expensive and its cost is rising, but most countries need a motorised transport system. One answer lies in the 'biomass' process by which molasses from sugar plantations and other vegetation is fermented with yeast to give alcohol. Most engines can be adapted to run on such alcohol, or 'gasohol' as it is sometimes called. Brazil has taken up this solution to the fuel problem in a substantial way and now produces more than twenty per cent of its motor fuel from alcohol, but this has a drawback. When commercial enterprises start production on a big scale they use a lot of agricultural land which may decrease food production and displace the peasant farmers who are then driven to seek work in the overcrowded towns.

All developing countries want to industrialise. For this they need power stations, and the present options seem to be hydroelectricity or nuclear power. Both are expensive to install and to run, yet without such energy resources there is little hope of making substantial improvements in standards of living. The gap between the developed and developing countries is not closing.

A developing country with little natural fuel or mineral wealth seems unlikely to go through an Industrial Revolution. Do you think that such a country:

Should be satisfied to maintain a low energy economy with a low standard of living and an unaltered culture?
Should try to establish enough industrial wealth to finance good medical and educational services for its citizens?
Can leap into the post-industrial age where advanced technological skills (or high standards of craft skills) can produce an economic return without large supplies of fuel or materials?

What will life be like in 500 years' time when the bulk of the world stocks of fossil fuels have run out? Try writing a short science fiction story.

Suggested Reading

Energy trends – A Statistical Bulletin Department of Energy

This is published quarterly and is packed with data about supply and demand for different forms of energy over the last two years.

New Sources of Energy G. Leach (J. M. Dent & Sons)

Energy and Human Needs Curran and Curran (Scottish Academic Press)

Both books are easy to read – 15 years upwards – and contain information about current energy problems.

The Force of Knowledge J. M. Ziman (Cambridge University Press)

This book was written for undergraduates but is well illustrated and good for the school library. The first chapter contains material about early steam engines.

Physics in Society Translated from the Dutch (obtainable through SISCON)

An excellent book for 16 years and upwards, especially those studying physics. Gives theoretical points in the appendix so can be used by all. Good on nuclear power and alternative energy in Holland.

Exploring Europe: Nuclear Energy Sussex European Research Centre, University of Sussex

This is a comprehensive source of data about the different countries in the EEC and the forms of energy that they use.

Nuclear Energy Questions Information Service on Energy, Ainslie Place Edinburgh

A study pack of booklets about nuclear energy and its possible hazards. Interesting on the mining of uranium; easy to read.

Technology for Development Centre for World Education

A booklet packed with one-page articles on different aspects of life in the less developed countries; drawings, cartoons. 14 years and upwards.

Running out of Fuel: Project Earth Ray Dafter (Wayland)

A simple book with plenty of pictures for the less able. Optimistic on alternative energy and pessimistic on nuclear power and rising energy consumption but attractive to leaf through.

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ISBN 0 631 91010 7