18 Energy resources

'If each Indian were to start consuming the amount of commercial energy a Briton does, that would mean the world finding the equivalent of an extra 3190 million tonnes of oil each year. Imagine what consuming that would do to the greenhouse effect, not to mention its effect on oil and other reserves.'

Mark Tully, *No Full Stops in India*, 1991

What are resources?

Resources have been defined as commodities that are useful to people although the value and importance of individual resources may differ between cultures. Although the term is often taken to be synonymous with **natural resources**, geographers and others often broaden this definition to include **human resources** (Figure 18.1). Natural resources can include raw materials, climate and soils. Human resources may be subdivided into people and capital. A further distinction can be made between **non-renewable resources**, which are finite as their exploitation can lead to the exhaustion of supplies (oil), and **renewable resources**, which, being a 'flow' of nature, can be used over and over again (solar energy). As in any classification, there are 'grey' areas. For example, forests and soils are, if left to nature, renewable; but, if used carelessly by people, they can be destroyed (deforestation, soil erosion).

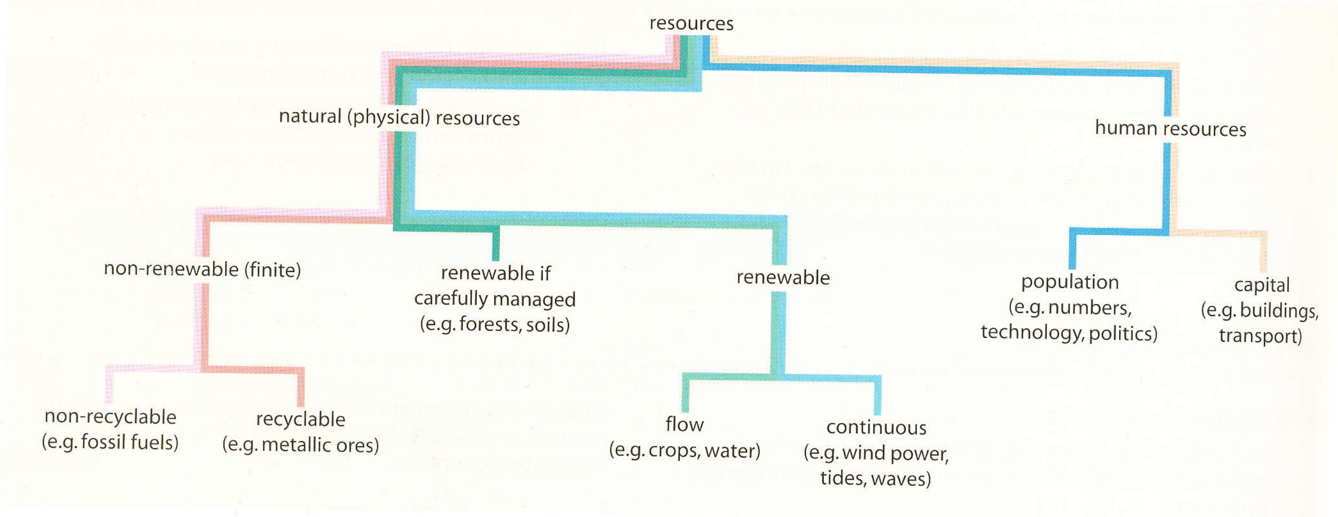
Reserves are known resources which are considered exploitable under current economic and technological conditions. For example, North Sea oil and gas needed a new technology and high global prices before they could be brought ashore; in contrast, tidal power still lacks the technology, and often the accessibility to markets, that are needed to allow it to be developed on a widespread, commercial scale.

Energy resources

The sun is the primary source of the Earth's energy. Without energy, nothing can live and no work can be done. Coal, oil and natural gas, which account for an estimated 88 per cent of the global energy consumed in 2007 (Figure 18.2) compared with 85.5 per cent in 1996, are forms of stored solar energy produced, over thousands of years, by photosynthesis in green plants. As these three types of energy, which are referred to as **fossil fuels**, take long periods of time to form and to be replenished, they are classified as non-renewable. As will be seen later, these fuels have been relatively easy to develop and cheap to use, but they have become major polluters of the environment. Nuclear energy is a fourth non-renewable source but, as it uses uranium, it is not a fossil fuel.

Figure 18.1

A classification of resources



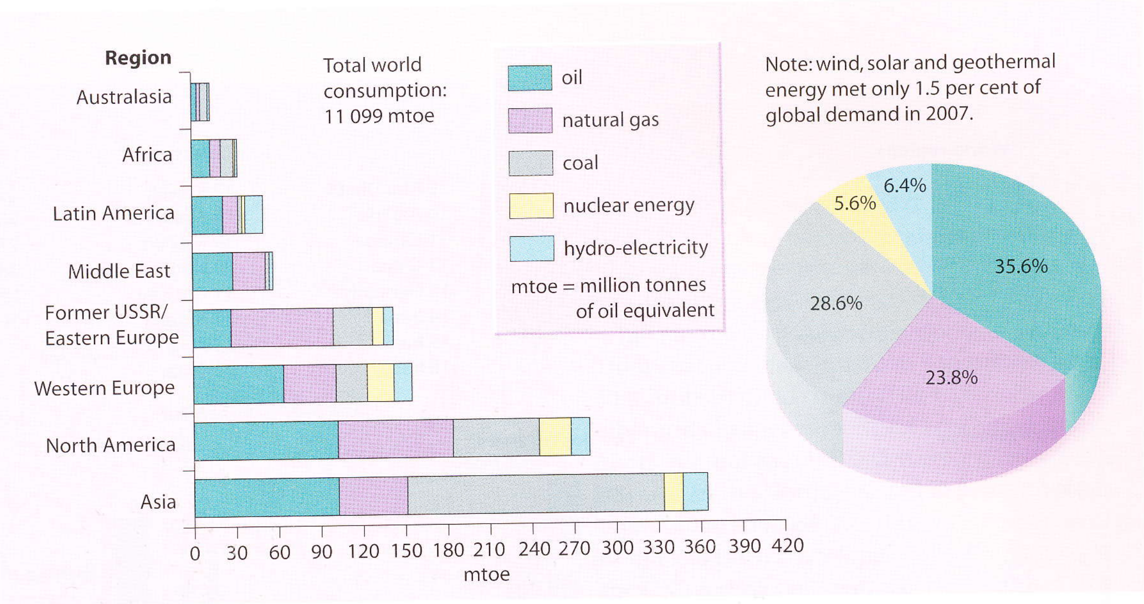


Figure 18.2

World energy consumption: by region, 2007

Renewable sources of energy are mainly forces of nature which can be used continually, are sustainable and cause minimal environmental pollution. They include running water, waves, tides, wind, the sun, geothermal, biogas and biofuels. At present, with the exception of running water (hydro-electricity), the wind and biomass, there are economic and technical problems in converting their potential into forms which can be used.

World energy producers and consumers

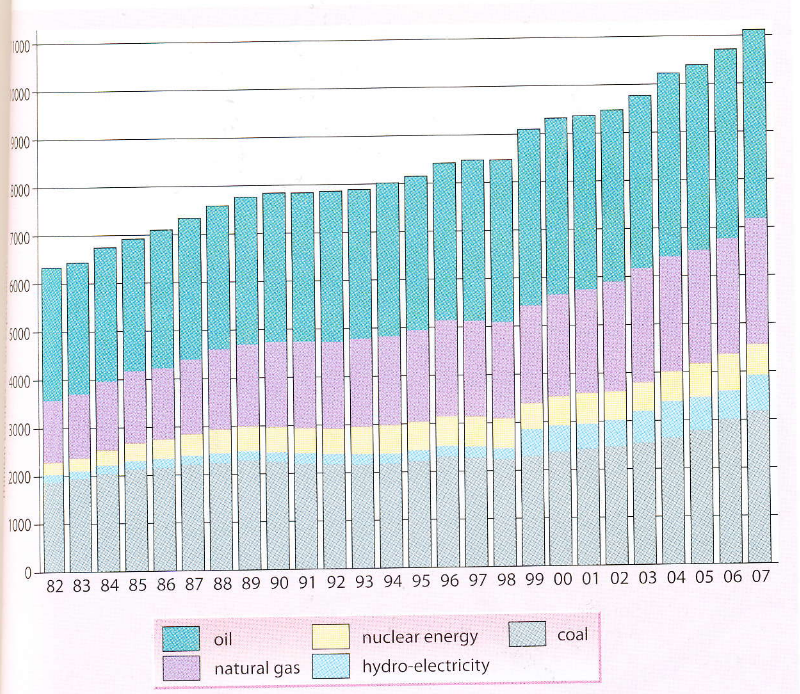
It has been estimated that, annually, the world consumes an amount of fossil fuel that took nature about 1 million years to produce, and that the rate of consumption is constantly increasing. This consumption of energy is not evenly distributed over the globe (Figure 18.2). At present, the 83 per cent of people living in the 'developing' countries consume only 47 per cent of the total energy supply.

Although recently the consumption of energy in 'developed' countries has begun to slow down, due partly to industrial decline and environmental concerns, it has been increasing more rapidly in 'developing' countries with their rapid population growth and aspirations to raise their standard of living (China's energy consumption doubled between 1997 and 2007). This led to a conflict of interest between groups of countries at the 1992 Rio Earth Summit conference. The 'industrialised' countries, with only 17 per cent of the world's population yet consuming 53 per cent of the total energy, wished to see resources conserved and, belatedly, the environment protected. The 'developing' countries, which blame the industrialised countries for most of the world's pollution and depletion of resources, considered that it was now their turn to use energy resources, often regardless of the environment, in order to develop economically and to improve their way of life.

The world's reliance upon fossil fuels (Figures 18.2 and 18.3) is likely to continue well into this century. However, while the economically recoverable reserves of coal remain high (Figure 18.4), the similar life expectancies of oil and natural gas are much shorter (coal: about 200–400 years; oil: about 50 years; natural gas: about 120 years). The distribution of recoverable fossil fuels is spread very unevenly across the globe, with the former USSR being well endowed with coal and natural gas; North America and parts of Asia with coal; and the Middle East with oil and natural gas (Figure 18.5). As these producers are not always major consumers, there is a considerable world movement of, and trade in, fossil fuels (Figure 18.6).

Figure 18.3

World energy consumption: by type, 1982–2007



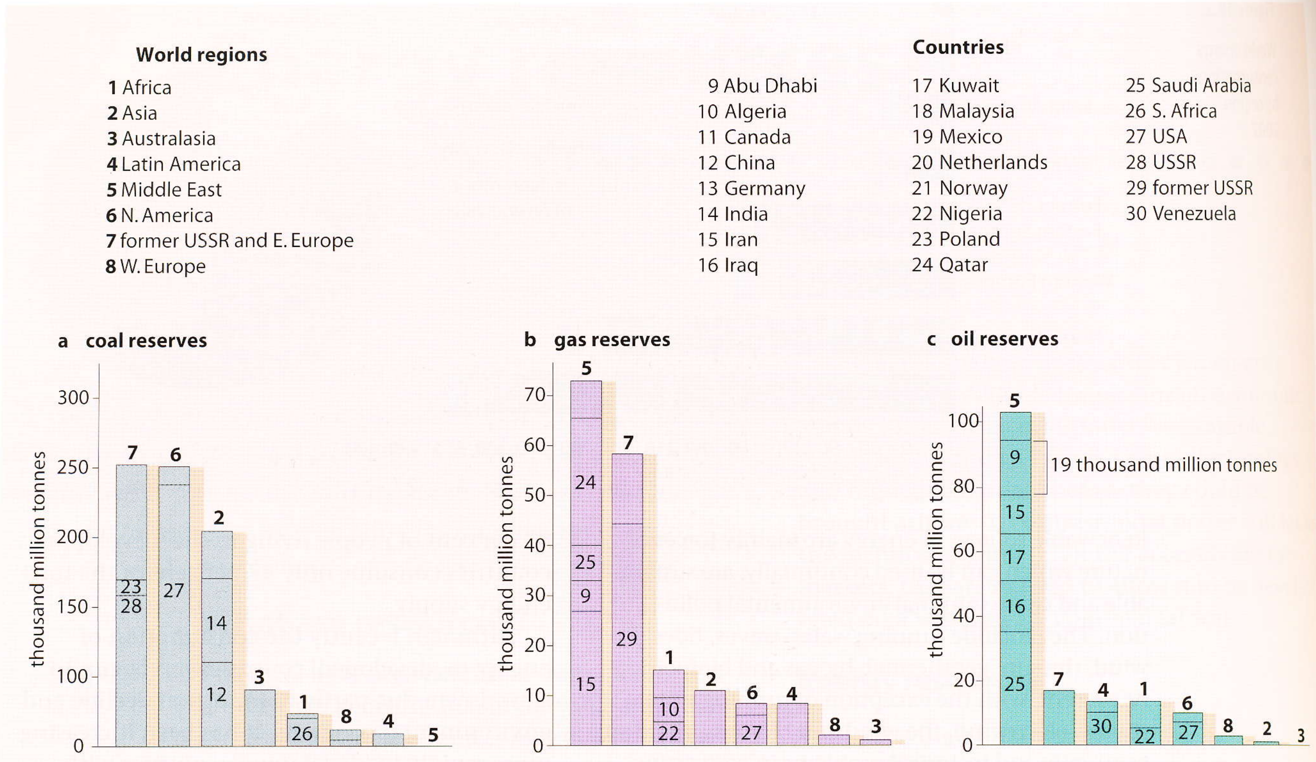


Figure 18.4

World reserves of coal, natural gas and oil, 2007

Figure 18.5

World producers of coal, natural gas and oil, 2007

	Coal	%	Natural gas	%	Oil	%
1	China	41.1	Russian Fedn	20.6	Saudi Arabia	12.7
2	USA	18.7	USA	18.8	Russian Fedn	12.6
3	Australia	6.9	Canada	6.2	USA	8.0
4	India	5.8	Iran	3.8	Iran	5.4
5	South Africa	4.8	Norway	3.0	China	4.8
6	Russian Fedn	4.7	Algeria	2.8	Mexico	4.4
7	Indonesia	3.4	Saudi Arabia	2.6	Canada	4.1
8	Poland	2.0	UK	2.5	UAE	3.5
9	Germany	1.6	China	2.4	Venezuela	3.4
10	Kazakhstan	1.4	Indonesia	2.3	Kuwait	3.3
	Others	9.6	Others	35.0	Others	37.8

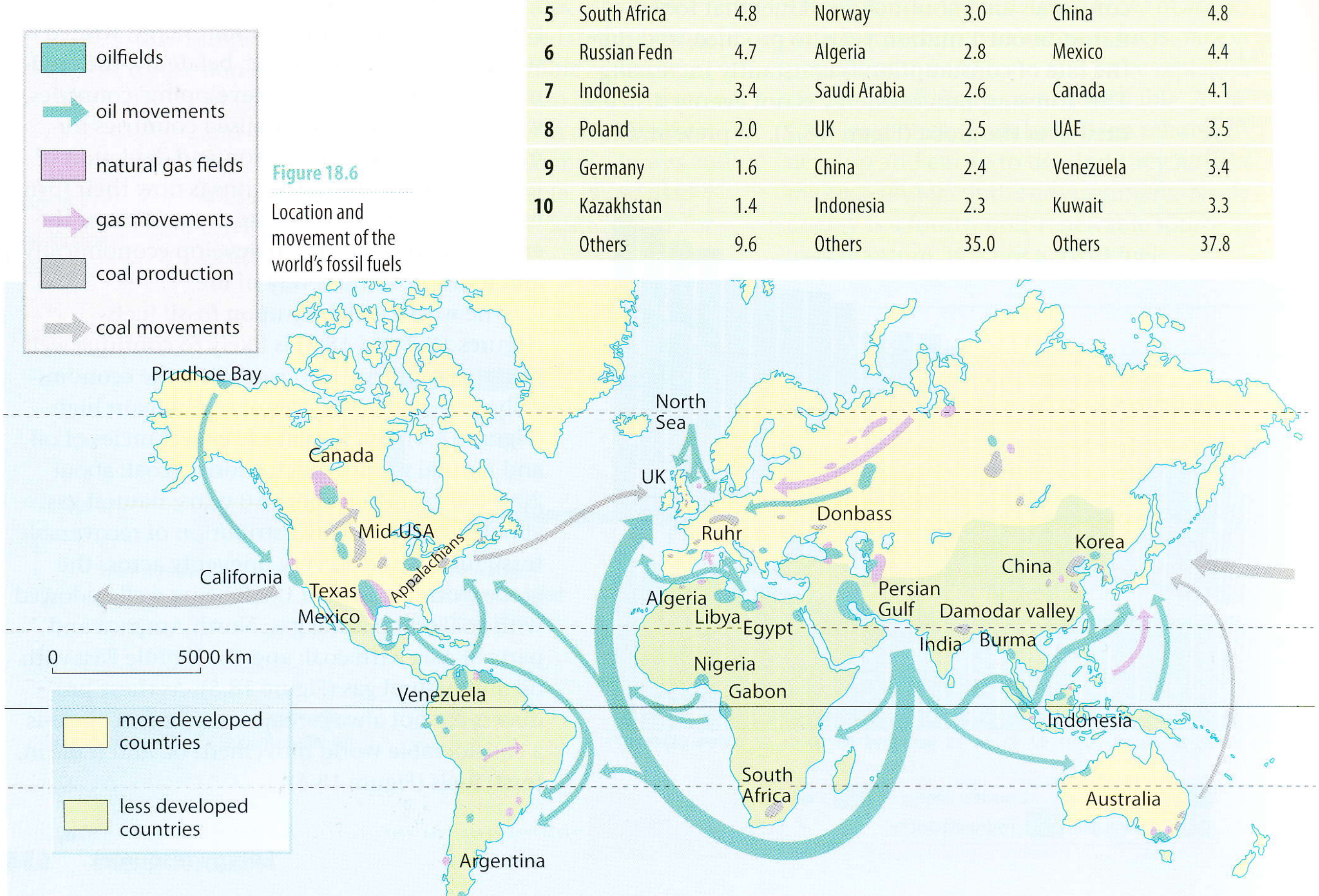


Figure 18.6

Location and movement of the world's fossil fuels

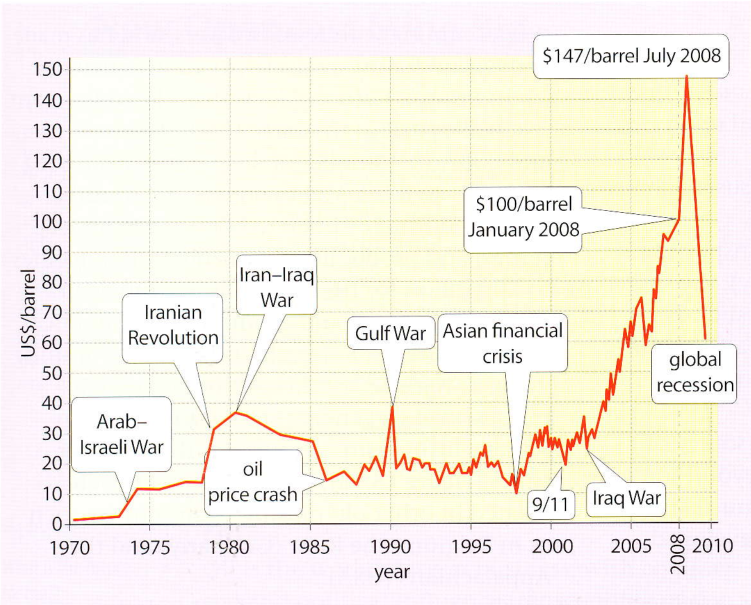


Figure 18.7

Crude oil prices, 1970–2008

Recent global trends

Energy consumption rose by an average of nearly 3 per cent per annum for the decade up to 2008 (Figure 18.3). The Asia-Pacific region accounted for two-thirds of this total growth, with China averaging over 8 per cent (Places 82, page 544) and India recently exceeding 6 per cent. In comparison, North America had only a slight rise, while Japan and the EU saw a decrease. Of the five main sources of primary energy, coal again, despite its contribution to climate change, saw the biggest growth. The year 2008 may be remembered as the year when the price of oil doubled that of its previous peak (Figure 18.7) before falling almost as rapidly with the onset of a global recession.

UK energy consumption

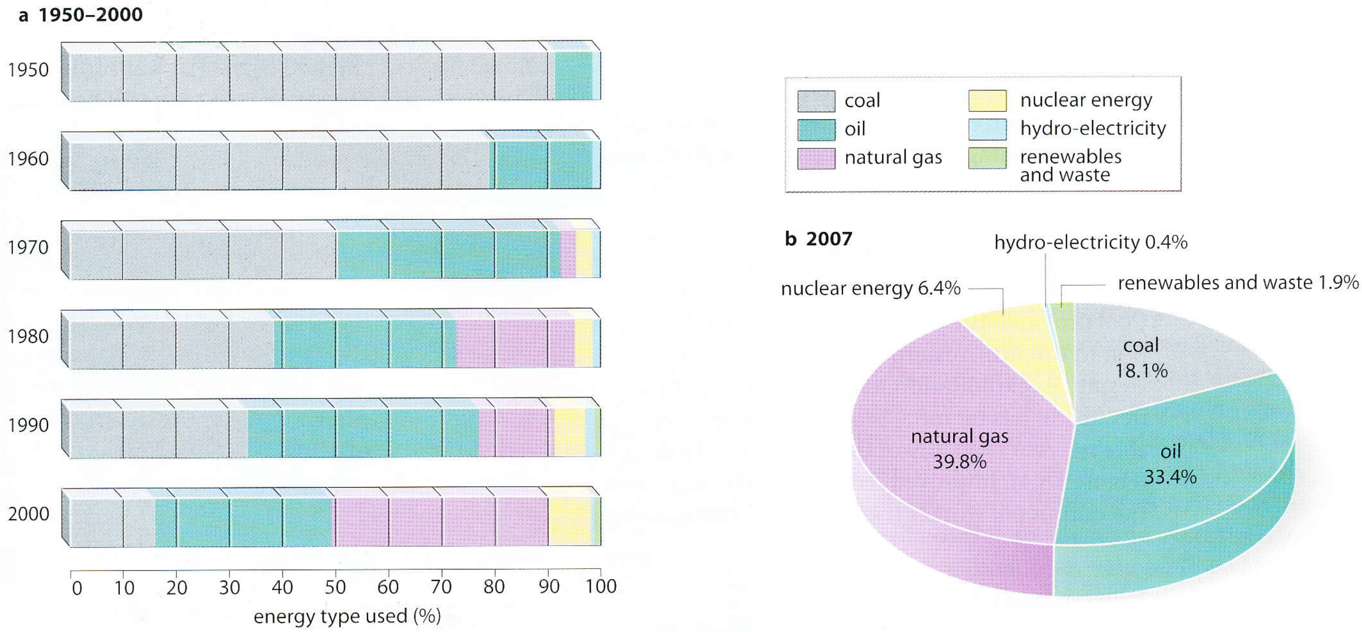
The UK has always been fortunate in having abundant energy sources. In the Middle Ages, fast-flowing rivers were used to turn water-wheels while, in the early 19th century, the use of steam, from coal, enabled Britain to become the world's first industrialised country. Just when the accessible and cheapest supplies of coal began to run short, natural gas (1965) and oil (1970) were discovered in the North Sea, and improvements in technology enabled the controversial production of nuclear power. Looking ahead to a time when the UK's reserves of fossil fuels become less available and their use environmentally unacceptable, Britain's seas and weather have the potential to provide renewable sources of energy using the wind, waves and tides. Even so Britain is, for the first time, having to rely on energy imports.

The total energy consumption in the UK rose from 152.3 mtoe (million tonnes of oil equivalent, a standard measure for comparing energy consumption) in 1960 to 233.5 mtoe in 2004, since when it has fallen back a little, to 226 mtoe in 2007. Of that, 97.5 per cent still came from fossil fuels and nuclear energy and only 2.5 per cent from renewables, including hydro-electricity and waste, despite pledges to increase renewables to 20 per cent by 2020 (Figure 18.8).

Energy consumption by final user continues to see a decline by industry (34 per cent in 1980 to 21 per cent in 2007), with domestic (28 per cent) and services (12 per cent) remaining fairly steady, and a rise by transport (25 per cent in 1980 to 39 per cent in 2007).

Figure 18.8

The UK's changing sources of energy, 1950–2007



Sources of energy

Decisions by countries as to which source, or sources, of energy to use may depend upon several factors. These include:

- Availability, quality, lifetime and sustainability of the resource.
- Cost of harnessing, as well as transporting (importing or within the country), the source of energy: some types of energy, such as oil, may be too expensive for less wealthy countries; while others, such as tides, may as yet be uneconomical to use.
- Technology needed to harness a source of energy: like costs, this may be beyond some of the less developed countries (nuclear energy), or may yet have to be developed (wave energy).
- Demands of the final user: in less developed countries, energy may be needed mainly for domestic purposes; in more developed countries, it is needed for transport, agriculture and industry.
- Size, as well as the affluence, of the local market.
- Accessibility of the local market to the source.
- Political decisions: for example, which type of energy to utilise or to develop (nuclear), or whether to deny its sale to rival countries (embargoes).
- Competition from other forms of available energy.
- Environment: this may be adversely affected by the use of specific types of energy, such as coal and nuclear; it may only be protected if there are strongly organised local or international conservation pressure groups such as Friends of the Earth and Greenpeace. More recently there has been growth in carbon trading (page 639) and the concept of our ecological footprint (page 379).

These factors will be considered in the next section, which discusses the relative advantages and disadvantages of each available or potential source of energy.

Non-renewable energy

Coal

Coal provided the basis for the Industrial Revolution in Britain, Western Europe and the USA. Despite its exploitation for almost two centuries, it still has far more economically recoverable reserves than any of the other fossil fuels (Figure 18.4). Improved technology has increased the output per worker (Figure 17.10), has allowed deeper mining with fewer workers, and has made conversion for use as electricity more efficient.

In Britain, both production and employment reached a peak in the early 1950s. Between then and 2007, the number of deep mines decreased from 901 to 6 (plus 25 opencast), the number employed from 691 000 to 6000 (4000 in deep mines) and production from 206 million tonnes to 20 million tonnes (9.6 million from deep mines). The social and economic consequences, especially in former single-industry coal-mining villages, were devastating, although people in these areas a generation or two later seem to have little desire to return to those earlier times (Figure 18.9a). Similar problems were created in other old mining communities such as in Belgium, the Ruhr (Germany) and the Appalachians (USA).

There are many reasons for this decline. The most easily accessible deposits have been used up, and many of the remaining seams are dangerous, due to faulting, and uneconomic to work. Costs have risen due to expensive machinery and increased wages. The demand for coal has fallen for industrial use (the decline of such heavy industries as steel), domestic use (oil- and gas-fired central heating) and power stations (now preferring gas). British coal has had to face increased competition from cheaper imports (USA and Australia), alternative methods of generating electricity (gas-fired) and cleaner forms of energy. Political decisions have seen subsidies paid to the nuclear power industry and a greater investment in gas rather than coal-fired power stations (the 'dash for gas' policy – page 538). Green pressures have also led to a decline in coal mining, which creates dust and leaves spoil tips; and in the use of coal to produce electricity, as this releases sulphur dioxide and carbon dioxide which are blamed for acid rain and for global warming (Case Study 9B). However, coal may still have an important future (Figure 18.9b) as alternative sources of energy run out – globally there are an estimated 155 years of high-quality coal left whereas oil and natural gas only have 45 and 65 years respectively. In the short term, coal is seen by emerging countries, such as China and India with their large reserves (Figure 18.5), as the main source for their increased energy consumption (Places 82, page 544); in the long term some countries will be dependent on the development of 'clean coal technologies' (as in Germany) and coal will be in competition with renewables.

New Opencast Mine Bid

Anger erupted after planners backed a new opencast pit in Northumberland – 12 months after saying it should be rejected. Hundreds of people have opposed UK Coal's bid to dig up 250 hectares of countryside on the edge of Ashington, in a six-year operation, only a year after the county council recommended the scheme be thrown out 'as opencasting would harm vital regeneration efforts'. Ashington, once one of the largest colliery towns in Britain, lies in an official 'constraint area' where county council policy says 'there is a strong presumption against opencast mining close to towns'. The planners appear to have changed their minds after the government gave permission for an opencast mine to be developed a few kilometres away at Cramlington, which is also in a 'constraint area', and since fears were raised that Britain may not, in the near future, have sufficient energy to 'keep its lights on'.

Abridged from the *Ashington Journal*, October 2008

Kingsnorth Coal-fired Power Station

The Cabinet is split over whether or not to approve a controversial plan for a £1 bn coal-fired power station at Kingsnorth on the Thames estuary in Kent. If the scheme went ahead it would be the first coal-fired station to be built in Britain for many years. The issue is, on one hand, the need to safeguard Britain's electricity supplies in the near future and, on the other, a test of the government's green credentials and assurances to reduce emissions.

E.ON UK, which has made the application, is hoping that the EU will choose this power station as part of their carbon capture experiment under which carbon emissions would be 'captured' and stored under the sea. A decision on the successful applicants is not expected for nine months. Environmental protest groups are not convinced with the assurance that, even if not selected, emissions from the power station would be lower than existing coal-fired stations.

Abridged from the *The Independent*, September 2008

Figure 18.9

What is the future for coal?

Oil

Oil is the world's largest business, with commercial and political influence transcending national boundaries. Indeed, several of the largest transnational enterprises are oil companies. Oil, like other fossil fuels, is not even in its distribution (Figure 18.6), and is often found in areas that are either distant from world markets or have a hostile environment, e.g. the Arctic (Alaska), tropical rainforests (Nigeria and Indonesia), deserts (Algeria and the Middle East) or under stormy seas (North Sea). This means that oil exploration and exploitation is expensive, as is the cost of its transport by pipeline or tanker to world markets. Oil, with its fluctuating prices, has been a major drain on the financial reserves of many developed countries and has been beyond the reach of most developing countries. Countries where oil is at present exploited can only expect a short 'economic boom' as, apart from several states in the Middle East where production may continue for a little longer, most world reserves are predicted to become exhausted within 45 years.

Figure 18.10

Milford Haven oil refinery

New technology has had to be developed to tap less accessible reserves. Before oil could be recovered from under the North Sea, large concrete platforms, capable of withstanding severe winter storms, had to be designed and constructed. Each platform, supported by four towers, had to be large enough to accommodate a drilling rig, process plant, power plant, helicopter landing-pad and living and sleeping quarters for its crew. The towers may either be used to store oil or may be filled with ballast to provide extra anchorage and stability. Two 90 cm trunk pipelines were laid, by a specially designed pipe-laying barge, over an uneven sea-bed to Sullom Voe on Shetland. Since then, production has spread northwards to even deeper and stormier waters west of Shetland. In 2007 the UK had 211 offshore oilfields although production from these had decreased by over 40 per cent since 1997.

On a global scale, oil production and distribution are affected by political and military decisions. OPEC (Figure 21.34) is a major influence in fixing oil prices and determining production – although even it is helpless in the face of international conflicts such as Suez (1956), the Iran–Iraq War (early 1980s) and the Gulf War (1991). Closer to home, recent British and EU fuel policies have favoured the gas and nuclear industries at the expense of oil. Oil is used in power stations, by industry, for central heating and by transport. Although it is considered less harmful to the environment than coal, it still poses many threats. Oil tankers can run aground during bad weather (*Braer*, 1993) releasing their contents which pollute beaches and kill wildlife (*Exxon Valdez*, 1989) or be hijacked by pirates (Somalia, 2008), while explosions can cause the loss of human life (Alpha Piper rig, 1988). To try to reduce the dangers of possible spillages and explosions, oil refineries have often been built on low-value land adjacent to deep, sheltered tidal estuaries, well away from large centres of population (Figures 18.10 and 18.12). Oil production is becoming increasingly concentrated in a few countries, all of whose current levels of production have been affected by geopolitics, both internal and external (Indonesia, Iran, Iraq, Kuwait, Mexico, Nigeria, Russia and Venezuela).

Natural gas

Natural gas has become the fastest-growing energy resource. It provides an alternative to coal and oil and, in 2007, it comprised almost a quarter of the world's primary energy consumption. Latest estimates suggest that global reserves will last another 65 years. Gas is often found in close proximity to oilfields (Figure 18.6) and therefore experiences similar problems in terms of production and transport costs and requirements for new technology. In 2008, Russia, Iran and Qatar announced an OPEC-type cartel that will control 60 per cent of the world's gas, a decision not welcomed by the EU which feared it could lead to a price rise and a means of achieving political goals. The UK had, in the latter part of the last century, a surplus of gas from its North Sea fields which resulted in the so-called 'dash for gas' by the electricity companies. By 2007, North Sea gas production had halved in ten years and the UK is now a net importer, some via a pipeline from Norway (2006) and an increasing amount from Russia. At present natural gas is considered to be the cheapest and cleanest of the fossil fuels.

Nuclear energy

During the 1950s, nuclear energy, with its slogan 'atoms for peace', was seen by many to be a sustainable, inexpensive and clean energy resource and by others as a potentially dangerous military weapon and a threat to the environment.

Figure 18.11

Major users of nuclear energy, 2007

Amount used (mtoe)		Proportion of total energy use (%)	
USA	192	France	76.8
France	100	Lithuania	64.4
Japan	63	Slovakia	54.3
Russia	36	Belgium	54.0
Germany	32	Ukraine	48.1
South Korea	32	Sweden	46.1
Canada	22	Armenia	43.5
Ukraine	21	Slovenia	41.6
Sweden	15	Switzerland	40.0
China	14	Hungary	36.8
UK	14	South Korea	35.3
Spain	13	Bulgaria	32.1

Nuclear energy uses uranium as its raw material. Compared with fossil fuels, uranium is only needed in relatively small amounts (50 tonnes of uranium a year, compared with 500 tonnes of coal per hour for coal-fired power stations). Uranium has a much longer lifetime than coal, oil or gas and can be moved more easily and cheaply. However, the development of nuclear energy, with its new technology, specially designed power stations and essential safety measures, has been very expensive. As a result, it has generally been adopted by the more wealthy countries, and even then only by those (Figure 18.11) lacking fossil fuels (Japan) or with significant energy deficits (UK, USA and France). As a source of electricity, it is fed into the National Grid; but, as a source of energy, it cannot be used by transport or for heating. The decision to develop nuclear power has been, universally, a political decision.

At its peak in the early 1990s, nuclear energy provided the UK with 30 per cent of its energy needs from 22 power stations. Since then plans for new stations have been dropped, and the plan for a fast-breeder reactor has been abandoned. By 2008, only ten stations remained open (Figure 18.12) and, by 2015, these will be reduced to four. While their closure will please the anti-nuclear lobby, it does not explain from where Britain is to get the replacement energy. This question has led to the government having to review its nuclear policy, especially when, with global warming and climate change so high on the environmental agenda, the nuclear industry can claim that the energy it produces is 'clean' and that improvements in technology have made it 'safer and more affordable' than in the past. In 2008, the government, partly also in an attempt to reduce Britain's increasing reliance on imported energy, opened the way for up to ten new stations to be built by 2020, the first by 2017.

Although nuclear power stations produce fewer greenhouse gases than thermal (coal-, oil- and gas-fired) power stations, they do present potential risks in three main areas: routine emissions of radioactivity, waste disposal, and radioactive contamination accidents. Routine emissions have been linked – without proven evidence – with clusters of increased leukaemia, especially in children, around several power stations (notably Sellafield and Dounreay). Radioactive waste has to be stored safely, either deep underground or at Sellafield. Every radioactive substance has a 'half-life', i.e. the time it takes for half of its radioactivity to die away.

Figure 18.12

Power stations in the UK with 50 MW or more capacity, 2008

Iodine, with a half-life of 8 days, becomes 'safe' relatively quickly. In contrast, plutonium 239, produced by nuclear reactors, has a half-life of 250 000 years and may still be dangerous after 500 000 years. The two worst radioactive accidents resulted from the melt-down of reactor cores at Three Mile Island in the USA (1979) and at Chernobyl in Ukraine (1986). Fortunately there was no such leak when the world's largest nuclear power plant was forced to close following an earthquake in Japan in 2007. It was mainly for economic and safety reasons that British nuclear power stations (Figure 18.12) were built on coasts and estuaries where there is water for cooling and cheap, easily reclaimable land well away from major centres of population. However, the British government had to agree in 1998, following renewed calls from several EU countries, to make a large reduction in discharges into the Irish Sea from Sellafield.

Renewable energy

With the depletion of oil and gas reserves during the early years of the 21st century and the unfavourable publicity given to all types of fossil fuels, especially regarding their contribution towards global warming, renewable energy resources are likely to become increasingly more attractive. They are likely to become more cost-competitive, offer greater energy diversity, and allow for a cleaner environment. As shown in Figure 18.1, there are two types of renewable energy:

- **Continuous sources** are recurrent and will never run out. They include running water (for hydro-electricity), wind, the sun (solar), tides, waves and geothermal.
- **Flow sources** are sustainable providing that they are carefully managed and maintained (Framework 16, page 499). Biomass, including the use of fuelwood, is sustainable in that it has a maximum yield beyond which it will begin to become depleted.

Hydro-electricity

Hydro-electricity is the most widely used commercially produced renewable source of energy (fuelwood is used by more people and in more countries). Its availability depends on an assured supply of fast-flowing water which may be obtained from rainfall spread evenly throughout the year, or by building dams and storing water in large reservoirs. The initial investment costs and levels of technology needed to build new dams and power stations, to install turbines and to erect pylons and cables for the transport of the electricity to often-distant markets, are high. However, once a scheme is operative, the 'natural, continual, renewable' flow of water makes its electricity cheaper than that produced by fossil fuels.

Although the production of hydro-electricity is perceived as 'clean', it can still have very damaging effects upon the environment. The creation of reservoirs can mean large areas of vegetation being cleared (Tucurui in Amazonia), wildlife habitats (Kariba in Zimbabwe) and agricultural land (Volta in Ghana) being lost, and people being forced to move home (Aswan in Egypt and the Three Gorges Dam in China – Places 82, page 544). Where new reservoirs drown vegetation, the resultant lake is likely to become acidic and anaerobic. Dams can be a flood risk if they collapse or overflow (Case Study 2B), have been linked to increasing the risk of earthquake activity (Nurek Dam in Tajikistan) and can trap silt previously spread over farmland (Nile valley, Places 73, page 490). Despite these negative aspects, many countries rely on large, sometimes prestigious, schemes or, increasingly in less developed countries, on smaller projects using more appropriate levels of technology (Case Study 18).

Wind

Wind is the most successful of the new renewable technologies. Wind farms are best suited to places where winds are strong, steady and reliable and where the landscape is either high or, as on coasts, exposed. Although expensive to build – wind farms cost more than gas or coal-fired power stations – they are cheap and safe to operate. Most of Britain's new wind farms are to be located offshore where, although more costly to construct, winds are more reliable than on land. As wind farms are mainly pollution free, they do not contribute to global warming or acid rain and they should significantly contribute to world commitments to reduce carbon dioxide emissions by 60 per cent by 2050. Winds, especially in Western Europe and California, are strongest in winter when demand for electricity is highest. Wind farms can provide extra income for farmers who could earn more from them than they could from growing a crop on the same-sized plot. Wind farms also create extra jobs for people living in rural areas and in the electricity generation supply chain. As fossil fuels become less available, countries will have to become increasingly dependent on renewables such as wind.

However, British environmentalists are now less supportive of wind power than they originally were. This is partly because many of the actual and proposed wind farms are in areas of scenic attraction, where they are visually intrusive, or too close to important wildlife habitats. In an attempt to make them more efficient, turbines are becoming increasingly tall – over 50 m on onshore wind farms and even higher on those located offshore, where some could be taller than the Canary Wharf tower. Elsewhere, local residents complain of noise and impaired radio and TV reception, while others claim that the rotating blades are a danger to birds, the turbines can affect airport radar systems, and that electricity costs are higher than for power from fossil fuels and nuclear energy. As yet, electricity companies cannot store surplus power for times when wind power cannot be produced, i.e. during calms or when the wind is less than about 15 km/hr which could be during very cold winter anticyclonic conditions (page 234); or during gales when winds are over 55 km/hr and wind farms must shut down for safety reasons. Both eventualities are times when demand is likely to be greatest.

Although the first large-scale wind farms were located in California (Figure 18.13) and the USA still has over one-quarter of the world's capacity, the fastest growth is in the EU, notably in Spain and Germany, and the emerging countries of China and India.

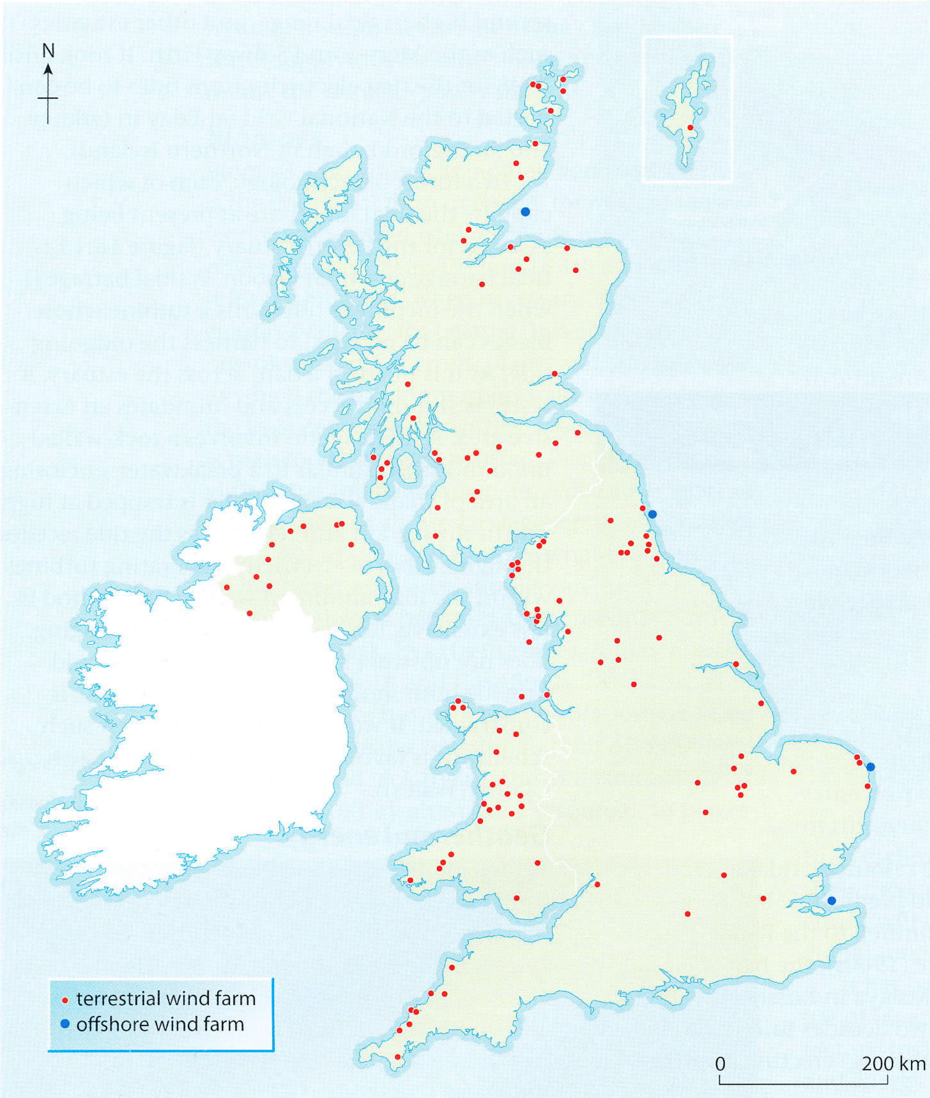
Places 81 California and the UK: wind farms

California

Most wind farms in the USA have been developed by private companies. The developers, who use either their own or leased land, sell electricity to electric utilities. At present, 90 per cent of the USA's capacity comes from California. California's wind farms are in an ideal location mainly because peak winds occur about the same time of year as does peak demand for electricity in the large cities nearby. Approximately 16 000 turbines within the state produce enough electricity to supply a city the size of San Francisco. The three largest wind farms are at Altamont Pass (east of San Francisco), Tehachapi (between the San Joaquin Valley and the Mojave Desert) and San Gorgonio (north of Palm Springs). The Altamont Pass, with 7000 turbines, is one of the largest wind farms in the world (Figure 18.13). The average wind speed averages between 20 and 37 km/hr. The land is still used for cattle grazing as there is only one turbine for every 1.5–2 ha.

Figure 18.13

Wind farm at Altamont Pass, California



The UK

Britain's first wind farm was opened in 1991 near Camelford in Cornwall. The farm, on moorland 250 m above sea-level and where average wind speeds are 27 km/hr, generates enough electricity for 3000 homes. In 2008, Britain had 188 operational wind farms, 7 of which were offshore, but these in total provided less than 1 per cent of the country's energy needs (Figure 18.14). With another 43 under construction (8 offshore) and 130 projected (8 offshore), the government hopes that, by 2010, 10 per cent of Britain's energy will come from renewables (60 per cent from the wind); and, by 2020, 20 per cent. To achieve this, another 4000 onshore turbines and 3000 offshore wind farms (with 11 000 turbines) will be required.

Figure 18.14

Wind farms in the UK, 2007

Solar energy

The sun, as stated earlier, is the primary source of the Earth's energy. Estimates suggest that the annual energy received from the sun (insolation) is 15 000 times greater than the current global energy supply. Solar energy is safe, pollution-free, efficient and of limitless supply. Unfortunately, it is expensive to construct solar 'stations', although many individual homes have had solar panels added, especially in climates that are warmer and sunnier than in Britain. It is hoped, globally, that future improvements in technology will result in reduced production costs. This would enable many developing countries, especially those lying within the tropics, to rely increasingly on this type of energy. In Britain, the solar energy option is less favourable partly due to the greater amount of cloud cover and partly to the long hours of darkness in winter when demand for energy is at its highest.

In 2008, South Korea opened the world's largest solar power plant. It covers the equivalent of 93 football stadiums and provides electricity for 100 000 homes.

Wave power

Waves are created by the transfer of energy from winds which blow over them (page 140). In western Europe, winter storm waves from the Atlantic Ocean transfer large amounts of energy towards the coast where it has the potential to generate the same amount of energy for the UK as wind does now. At present there are two experimental schemes off the Scottish coast, making it ten years behind wind power. The first, LIMPET, is a 500 kW shoreline oscillating water column in Islay; the second is the 750 kW Pelamis sea snake – a hinged contour device – in Orkney (the Portuguese are now using Pelamis commercially).

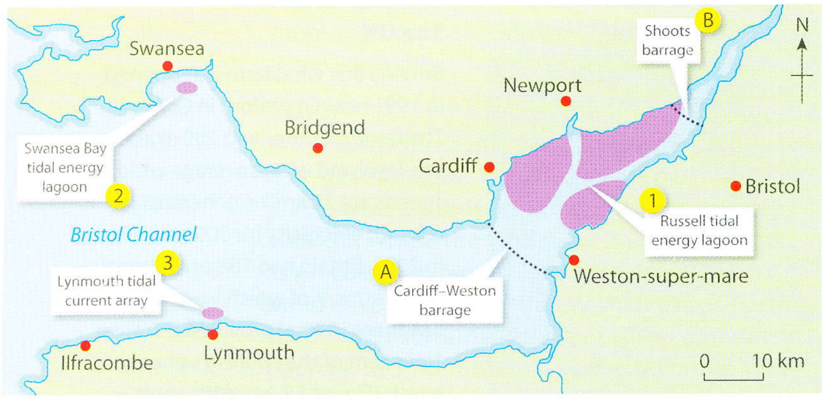


Figure 18.15

A Severn barrage or tidal lagoons?

	Barrages		Lagoons
	Cardiff–Weston	Shoots	Russell
Cost	£15 bn	£1.5 bn	est. £10 bn
UK's energy supply	5%	0.75%	7%
Generation cost	5p kW/hr	?	2–2.5p kW/hr
Impounded areas	480 km^2	very little	300 km^2
Length of barrage/ walls	16 km	4 km	100 km
Environment	low carbon; loss of feeding grounds for up to 50 000 birds	low carbon; less loss of feeding grounds	low carbon; little loss of feeding grounds

Tidal energy

Of all the renewable resources, tidal energy is the most reliable and predictable but to date major schemes are limited to the Rance estuary in north-west France (1960s), the Bay of Fundy in eastern Canada, Kislaya in Russia and Jiangxia in China. For over two decades Britain has talked about (and is still debating) erecting a barrage across the Severn estuary, which has the world's second highest tidal range, and other estuaries such as the Mersey and Solway Firth. It took until 2008 for the first electricity from tides to be connected to the National Grid (at Eday in Orkney and Strangford Lough in Northern Ireland).

Two forms of technology, each of which exploits the tidal range, are at present being assessed for the Severn estuary (Figure 18.15): tidal barrage and tidal lagoon. A tidal barrage is when the incoming tide turns a turbine whose blades can be reversed to harness the outgoing tide. As it is in effect a dam across the estuary, it restricts shipping access and inundates an extensive area. A tidal lagoon involves a rock-walled impoundment, similar to a breakwater, enclosing an area of shallow water. Water is trapped at high tide in the lagoon and released as the tide recedes through a bank of electricity-generating turbines within the impoundment walls. This method is less extensive, less environmentally damaging, does not obstruct shipping access and would provide both more and cheaper electricity. If constructed, it would be the world's first such scheme (it is favoured by Friends of the Earth Cymru (Wales)).

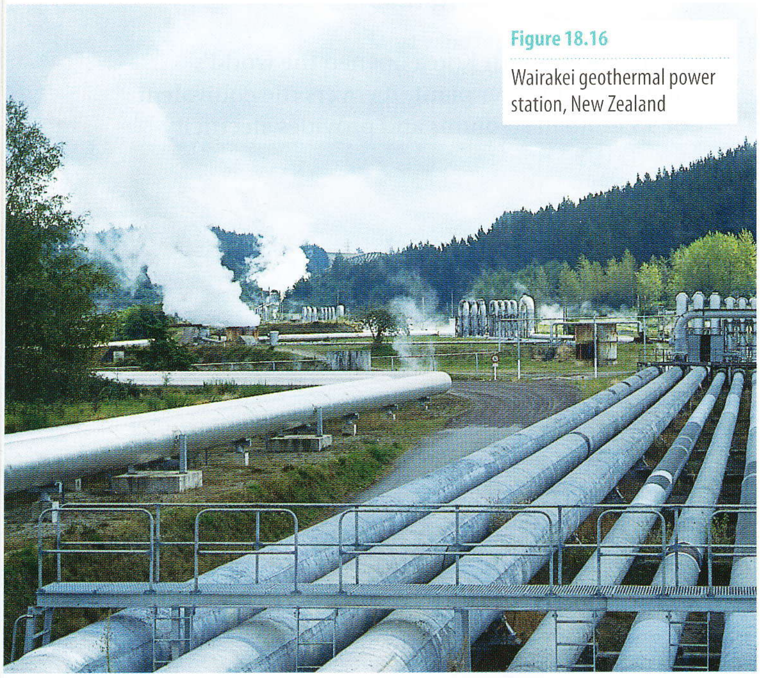


Figure 18.16

Wairakei geothermal power station, New Zealand

Geothermal energy

Several countries, especially those located in active volcanic areas, obtain energy from heated rocks and molten magma at depth under the Earth's surface, e.g. Iceland, New Zealand, Kenya, and several countries in central America (Figure 18.16). It is also derived from hot springs and by tapping aquifers which contain naturally hot water. Cold water (Figure 18.17) is pumped downwards, is heated naturally and is then returned to the surface as steam which can generate electricity. Geothermal energy does pose

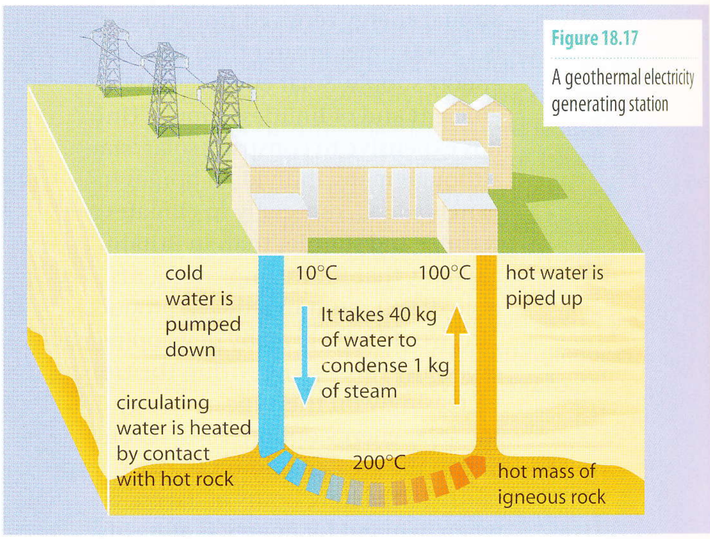


Figure 18.17

A geothermal electricity generating station environmental problems as carbon dioxide and hydrogen sulphide emissions may be high, the water supply can become saline, and earth movements can damage power stations.

Biomass

Biomass, also known as biofuels and bioenergy, is the dominant form of energy for most of the world's population who are living in extreme poverty (page 609 and Figure 18.19) and who use it for cooking and, when necessary and if sufficient is available, for heating. It is obtained from organic matter, i.e. crops, plants and animal waste, of which the most important to those living in the least developed countries, especially in Africa, is **fuelwood**. Trees are a sustainable resource, providing that those cut down are replaced, which costs money, or allowed to regenerate, which takes time – but money and time are what these people do not have. As nearby supplies are used up, collecting fuelwood becomes an increasingly time-consuming task; in extreme cases, it may take all day (Figure 18.18 and Case Study 18). Many of these countries have a rapid population growth, which adds greater pressure to their often meagre resources, and lack the capital and technology to develop or buy alternative resources. In places where the demand for fuelwood outstrips the supply, and where there is neither the money to replant nor the time for regeneration, the risk of desertification and irreversible damage to the environment increases – i.e. the cycle of environmental deprivation (Figure 18.18).

Figure 18.18

Collecting fuelwood, sub-Saharan Africa

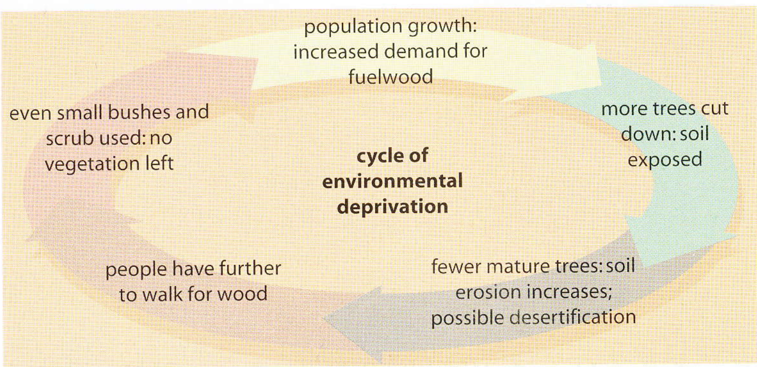


Figure 18.19

The cycle of environmental deprivation

The use of biomass is generally considered to be a 'carbon neutral' process as the carbon dioxide released in the generation of energy balances that absorbed by plants during their growth. This is not, however, applicable to those parts of Africa where animal dung is allowed to ferment to produce methane gas. While the methane, a greenhouse gas, provides a vital domestic fuel, it means that the dung cannot be spread as a fertiliser on the fields.

Biomass can also be used to produce **biofuels** (**bioenergy**), the first being used in Brazil where sugar cane was allowed to ferment to produce bio-ethanol which was then used as a vehicle fuel that was cheaper than petrol. More recently, and more widely used, biodiesel comes from oil palm, a use that has led to increased forest clearances for that crop in Malaysia; in the EU oilseed rape, and in the USA maize, are being grown for the same purpose. Governments are viewing the use of this renewable resource as a way of reducing their carbon emissions without foreseeing that their increased growth, at the expense of food crops, will lead to food shortages and rising global food prices.

It has become apparent that the sustainable use of bioenergy requires a balancing of several factors, including the competition between food and energy security, the effects on rural development and on agricultural markets and food prices, as well as the effects on the environment. In 2007, biomass accounted for 82 per cent of the UK's renewable energy sources (wind 9 per cent, and hydro-electricity 8 per cent), the majority of which was derived from landfill gas and waste combustion. It is also the fastest-growing renewable in the EU while its use in the USA is said to be equal to the output of ten nuclear power stations.

Hydrogen

Hopes are high for the development of a fuel cell in which a chemical reaction takes place that generates electricity from hydrogen. The reaction produces clean, efficient energy in a process that releases nothing more damaging to the environment than water vapour. Although developed countries see the petrol-free hydrogen car as a major breakthrough in transport, fuel cells hold potential for developing countries too as they are equally economic on a small scale and require little maintenance.

Energy conservation through greater efficiency

One of the UN's main objectives since the first 'Earth Summit' on the environment (Rio de Janeiro 1992) has been to try to get countries to agree to set global limits and timescales in reducing harmful emissions from vehicles, factories and power stations and to seek methods of greater energy efficiency. Since then, progress has been limited partly due to opposition from vested interests and, until more recently, a lack of political will. However, there have been some successes. Several industries, including the steel industry, have improved their techniques, reducing the amount of energy needed; factories have made savings by reducing to a single source of electricity needed for heating, lighting and operating machinery; and the number of coal- and oil-fired power stations has been reduced in favour of gas (a cleaner greenhouse gas). At home, heat loss has been reduced through roof and wall insulation and double glazing, while for lighting the EU is trying to enforce the use of energy-saving bulbs.

Places 82 China: changes in energy production and consumption

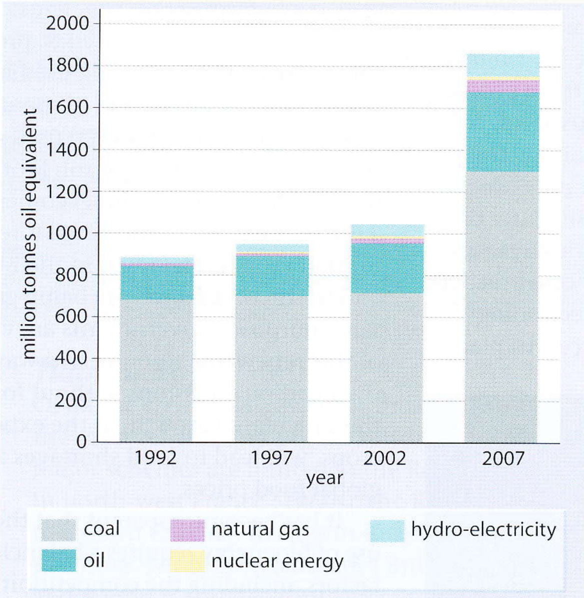


Figure 18.20

Energy consumption in China, 1992–2007

In the early 1990s, China's energy industry was dominated by coal (Figure 18.20), which was not surprising since the country was producing nearly two-fifths of the world's total (Figure 18.5). Coal is mined in most parts of the country, although production is lower to the south of the Yangtze River and least in the mountains to the west (Figure 18.21). With industry, transport and homes all so reliant upon the burning of coal in one form or another, many Chinese cities experienced severe atmospheric pollution (Figure 18.22), and China was blamed for releasing annually 10 per cent of the world's greenhouse gases. The remainder of China's energy budget was made up from oil, in which it was self-sufficient, and hydro-electricity. The fact that the country could provide sufficient energy for its needs was because, despite having such a large population, the country's standard of living and consumption of energy was low and it had yet to embark on the rapid economic development seen in the late 1990s and early 21st century. Even so, in 1995 China was ranked second in the world for generated energy, mainly from its thermal and hydro-electric power stations, and generating capacity.

Since the turn of this century and as China has become, economically, the world's most rapidly emerging country, there has been a huge increase in both its energy production and consumption, especially of coal, hydro-electricity and imported oil (Figure 18.20). This emergence (Chapter 21) has had a major effect on the global economy.

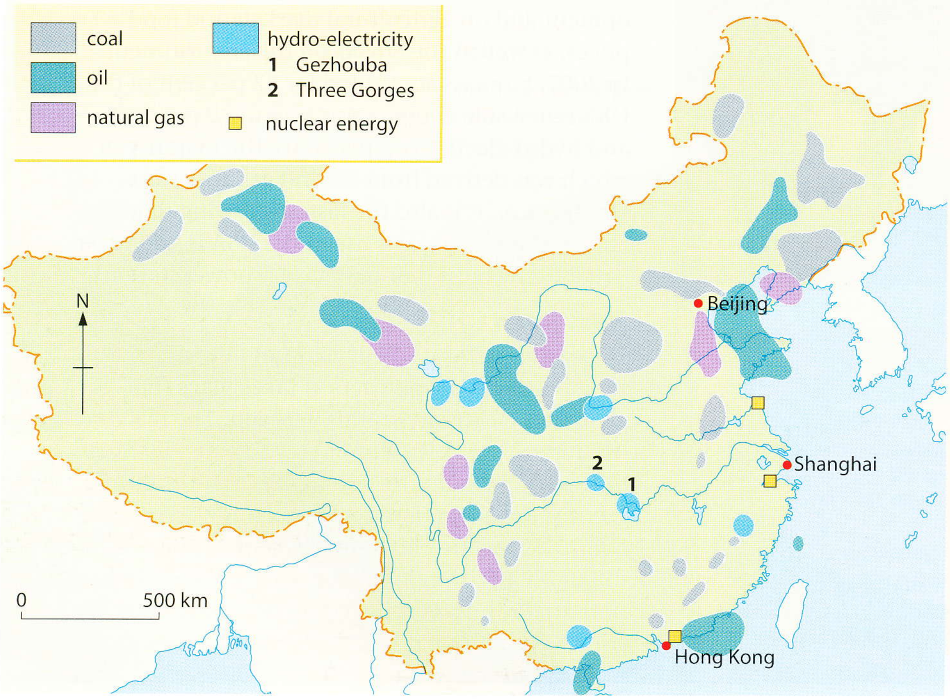


Figure 18.21

Energy resources in China

Figure 18.22

Atmospheric pollution over Chengdu

Coal still accounts for 70 per cent of China's energy consumption (Figure 18.20), despite its known effect on global warming and the pollution it causes in Chinese cities. Production almost doubled between 2002 and 2007 to meet the growing demand, despite a continually high rate of mining accidents and resultant deaths (Figure 18.23a). As the country's road and air transport systems develop, an increasing amount of oil has to be imported, mainly from the Middle East. This increase was partly to blame for a world shortage of oil in 2008 that led to the record high global price per barrel (Figure 18.7).

a

China's dependence on coal continues amid the incidence of accidents – 16 miners were killed and 46 injured in a mine blast last week – and claims of inefficient mining methods and high levels of pollution. In the last few years more than 18 000 small mines have either been closed, or merged with larger ones, but 14 000 are still operating. This number will be reduced further to 10 000 by 2010. Two effects of the merging of small mines have been a doubling in coal production and a drop in fatalities. In 2007, when 2900 died – 450 fewer than in the previous year – for every million tonnes of coal produced, the death toll at small mines was eight times that of the larger state-owned ones as the latter are believed to pay more attention to safety.

October 2008

b

China, now the world's second biggest gas consumer, plans to boost its own production by 50 per cent by 2010 by which time gas will have increased its share of the nation's total energy consumption from 3.5 per cent to 5.3 per cent. However, China will still have to import a significant amount which it will do through a second west–east pipeline at present being built to connect the Central Asian countries, notably Turkmenistan, with the energy-thirsty eastern and southern regions that include Shanghai and Guangdong.

November 2007

c

The first nuclear power reactor to be built in China (early 1990s) was at Qinshan in Zhejiang Province to the south of Shanghai. Since then six more reactors have been added to the complex. A second site is at Daya Bay (2002) in Guangdong Province where two reactors now provide energy for Shenzhen and Guangzhou, while a third at Lianyungang (2007) in Jiangsu Province, equidistant between Shanghai and Beijing, also has two reactors. All these reactors are second-generation, but work has just begun near Qinshan on a new third-generation type reactor.

June 2008

d

The last generator of China's Three Gorges Dam went online yesterday, meaning that the world's largest hydropower plant has become fully operational – five years after the first of the 26 turbines in the project's original plan began producing energy. The Three Gorges is now, in 2008, producing 58 per cent of the country's total hydro-electricity. The original plan has since been expanded to include six more generators which will be completed by 2012.

October 2008

Figure 18.23

Changes in coal, natural gas, nuclear power and hydro-electric power, adapted from *China Daily*

In comparison, consumption of natural gas and nuclear power is small but both show an increase (Figure 18.23b and c). Of the renewable sources of energy, hydro-electricity is by far the most important and is expected to become even more so as fossil fuels, as they run out, cannot go on satisfying China's rising needs for energy and as the country looks for cleaner options. Schemes such as the Three Gorges (Figures 18.23d and 18.24) are predicted to account for 28 per cent of China's total power generation by 2015.

Figure 18.24

The Three Gorges Dam on the Yangtze River

Development and energy consumption

To many people, especially in developed countries, economic development is linked to the wealth of a country, with wealth being measured by GDP per capita (page 606). Of several other variables that can be used to measure development, one is energy consumption per capita – i.e. how much energy, often given in tonnes of coal or oil equivalent, that each person in a country uses per year. Consequently a correlation between the wealth of a country and energy consumption might be expected (Framework 19, page 612).

The log-log graph in Figure 18.25 seems to show that there is a good, positive correlation between the two variables, i.e. as the wealth of a country increases, so too does its energy consumption. The huge gap in energy consumption between the developed and the developing world is shown in Figure 18.26. Note also that those countries above the line in Figure 18.25 tend to have more natural energy reserves (Russia – gas, Saudi Arabia – oil; Zambia – hydro-electricity) than those below the line (Italy, Peru).

Energy is the driving force behind most human activities, so it is fundamental to development. Energy allows people to make greater use of the resources that they have. According to Practical Action (Case Study 18 and Places 90, page 577):

'reliable, accessible and affordable energy supplies can play an important role in improving living conditions in the developing world. They provide light and heat for homes, and power workshops that create jobs and generate wealth. Poor people in developing countries face particular problems in securing energy for their daily needs. This is a pressing issue in rural areas where most people live. More than half the world's population relies upon biomass fuel (usually wood but also charcoal, crop residues or animal dung). Poor people cannot afford alternative fuels such as gas or kerosene. National grids mainly serve urban areas, or large industrial operations; it is prohibitively expensive to extend them far into the countryside. In places where there are renewable energy resources such as the sun, wind and water, communities often lack the knowledge, expertise and capital needed to install the most appropriate system.'

Figure 18.25

Correlation between GDP (US$) and energy consumption, 2008

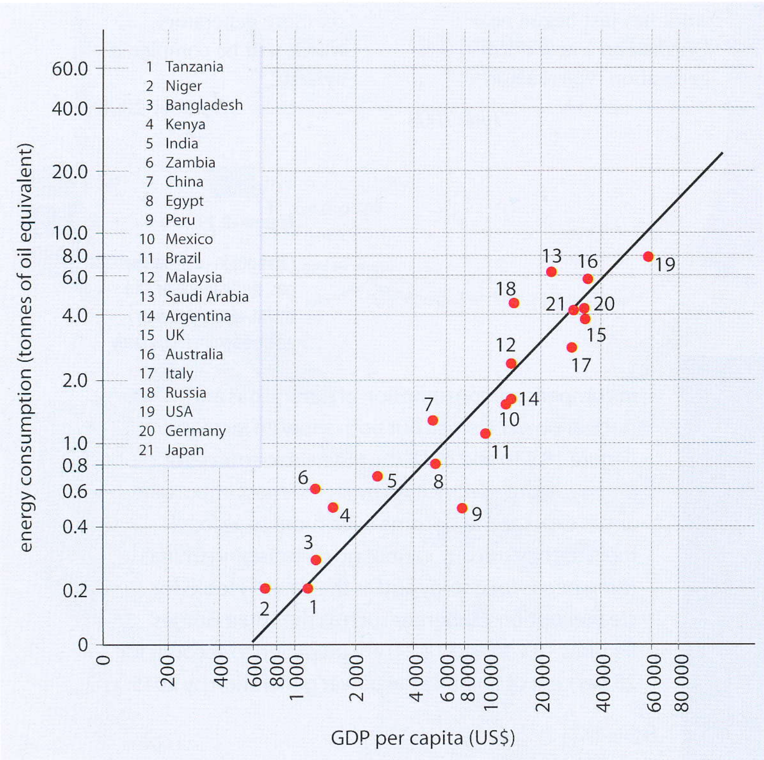
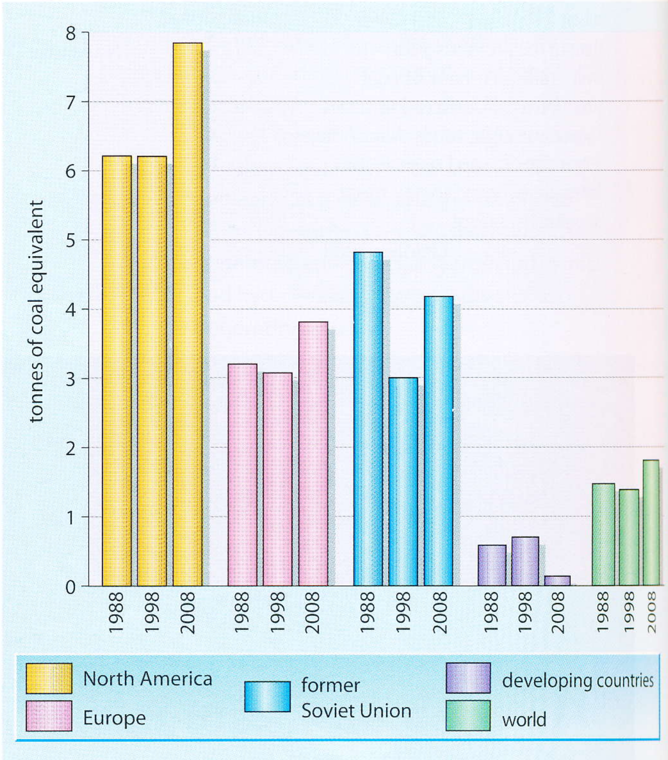


Figure 18.26

Energy consumption per capita in the developed and developing worlds



Appropriate technology: micro-hydro in Nepal

Case Study 18

'An Appropriate Technology is exactly what it says – a technology appropriate or suitable to the situation in which it is used [page 576]. If that situation is a highly industrialised urban centre the appropriate technology may well be "high tech". If, however, the situation is a remote Nepalese village "appropriateness" will be measured in the following terms:

- Is it culturally acceptable?
- Is it what people really want?
- Is it affordable?
- Is it cheaper or better than alternatives?
- Can it be made and repaired with local material, by local people?
- Does it create new jobs or protect existing ones?
- Is it environmentally sound?

For many decades "Aid" meant sending out the same large-scale, expensive, labour-saving technologies that we use: huge hydro-electric schemes, coal-fired power stations, diesel-powered generators. In some cases, for example towns and industrial areas, these have been appropriate. But such schemes do not reach the poorer communities in the rural areas. What was needed was some way of using local resources appropriately, and best of all some way of using renewable resources to decrease the need for reliance on outside help. Wind, solar and biogas energy are possibilities, but another resource widely available and already in use for thousands of years is water. Water is attracting much attention in the search for renewable sources of energy. However, despite continuing public outrage at the devastating impact of large hydro-electric schemes on people's livelihoods and the environment [page 539 and Places 82], vast sums of money continue to be pumped into big dams and other inappropriate power generation plans. On the other hand, the intermediate approach, through small-scale hydro, has no negative impact on the environment, offers positive benefits to the local community, and uses local resources and skills.'

Practical Action

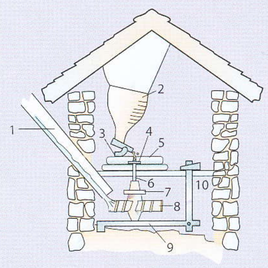
Practical Action and micro-hydro in Nepal

'The small Himalayan kingdom of Nepal ranks as one of the ten poorest countries in the world. Around 90 per cent of its 19 million people earn their living from farming, often at a subsistence level. The Himalaya mountains offer Nepal one vast resource – the thousands of streams which pour down from the mountains all year round. Nepali people have harnessed the power in these rivers for centuries, albeit on a small scale [Figure 18.27].

About 20 years ago, two local engineering workshops began to build small, steel, hydro-power schemes for remote villages. These turbines have the advantage of producing more power than the traditional mills, as well as being able to run a range of agricultural processing machines [Figure 18.28]. Practical Action first became involved in Nepal's micro-hydro sector in the late 1970s when the local manufacturers asked for help in using their micro-hydro schemes to generate electricity.

In the mid-1980s, Practical Action ran two training courses on micro-hydro power aimed at improving the technical ability of the nine new water turbine manufacturers that had been established in Nepal. These courses were very successful and prompted an agreement between Practical Action and the Agricultural Development Bank (the agency which funds micro-hydro power in Nepal) to collaborate on the development of small water turbines for rural areas. This work not only improved and extended the range and number of micro-hydro schemes in Nepal, but also established Practical Action as a leader in the field. In 1990 Practical Action was included in a government task force investigating the whole area of rural electrification; and in 1992 Practical Action was asked by the government to help establish an independent agency to promote all types of appropriate energy in rural areas of the country.'

Practical Action



1 chute delivering the water to the paddles of the wheel
2 grain hopper (basket)
3 device to keep the grain moving
4 metal piece to lock top of shaft in upper millstone
5 grinding stones
6 metal shaft
7 thick wooden hub
8 wooden horizontal wheel, with obliquely set paddles attached to hub
9 metal pin and bottom piece
10 lifting device to adjust gap between millstones

Figure 18.27

Cross-section of a traditional Nepali water mill

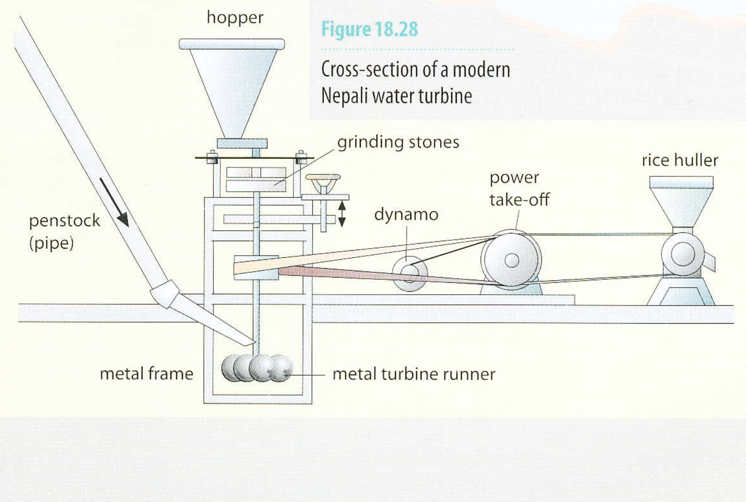


Figure 18.28

Cross-section of a modern Nepali water turbine

Appropriate technology: micro-hydro in Nepal

'Water power, harnessed using water wheels or *ghattas*, has been used for centuries for grinding corn. The micro-hydro system in the village now has improved the efficiency of milling, so that what used to take a woman four hours to grind by *ghatta* can be done in fifteen minutes. The power can also be used for dehusking rice and extracting oil from sunflower seeds [Figure 18.29].

The mechanical power produced by Ghandruk's micro-hydro system is also converted to electric power, which is distributed to every house in the village. Apart from the obvious benefit of lighting, many households are starting to use electric cookers or *bijuli dekchis*, which work like slow cookers [Figure 18.29].

Women are turning to *bijuli dekchis* because they reduce smoke levels in the kitchen, they save time by reducing the amount of firewood the family needs to collect, and they are more convenient and cook faster than traditional stoves. In a country ravaged by deforestation – villagers spend up to 12 hours on a round trip to collect wood – fuel saving is becoming more and more important.

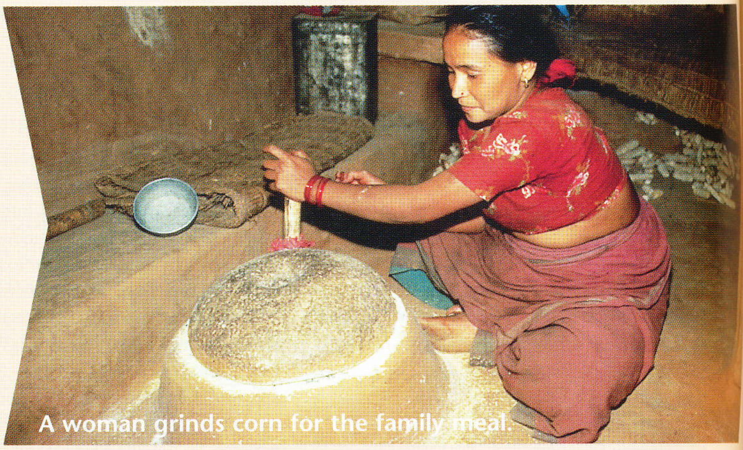
Micro-hydro schemes like the one in Ghandruk work because the community has "ownership" of the scheme by participating in its planning, installation and management; because the machinery needed can be made and maintained by local manufacturers using local materials available in the country; and because production and consumption are linked within a community.

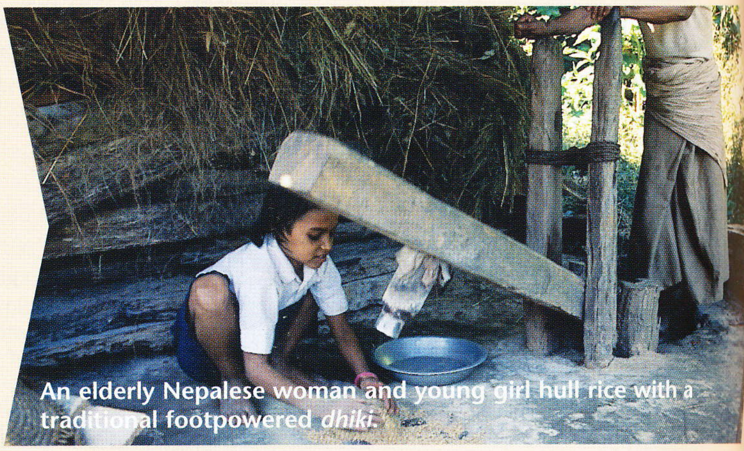
The lives of villagers all over Nepal are literally being lit up by micro-hydro schemes, and the country could serve as a model for decentralised, sustainable energy production. Already, 700 mechanical and 100 electrical schemes have been installed.

Much of the impetus for the development of hydro in Nepal initially stemmed from the absence of fossil fuel reserves to exploit. However, if the Government can resist the temptations of big dam schemes and the dollars being thrown at them by the big, international donor agencies, it could have the last laugh watching the rest of the world scrabble for the last of fossil fuel reserves.' Practical Action

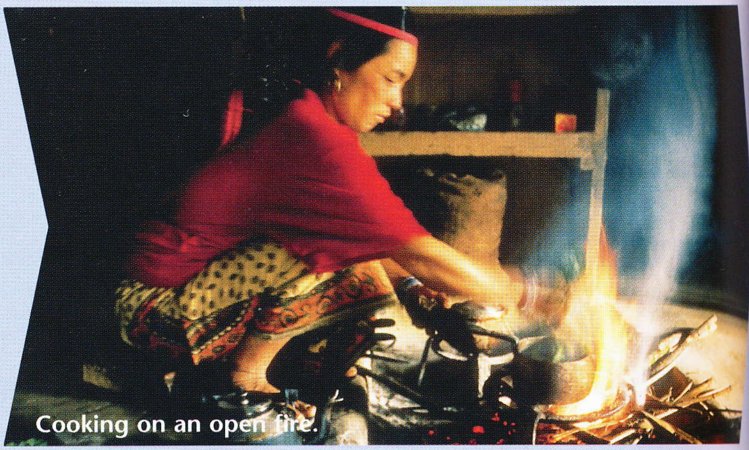
Life before power

Crop processing


A woman grinds corn for the family meal.


An elderly Nepalese woman and young girl hull rice with a traditional footpowered *dhiki*.

Cooking


Cooking on an open fire.

Living

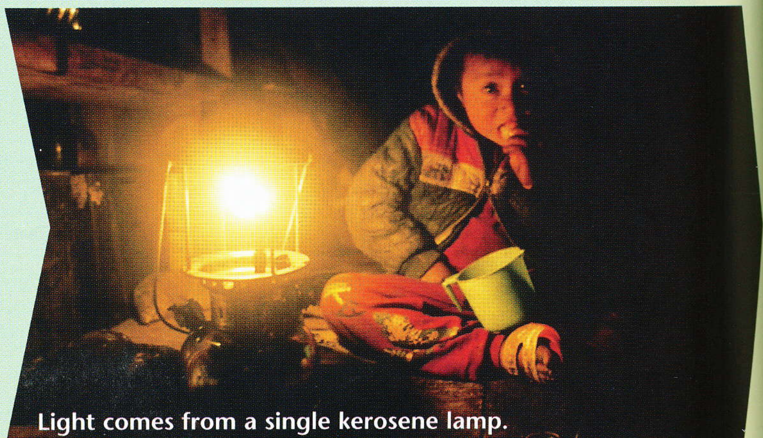
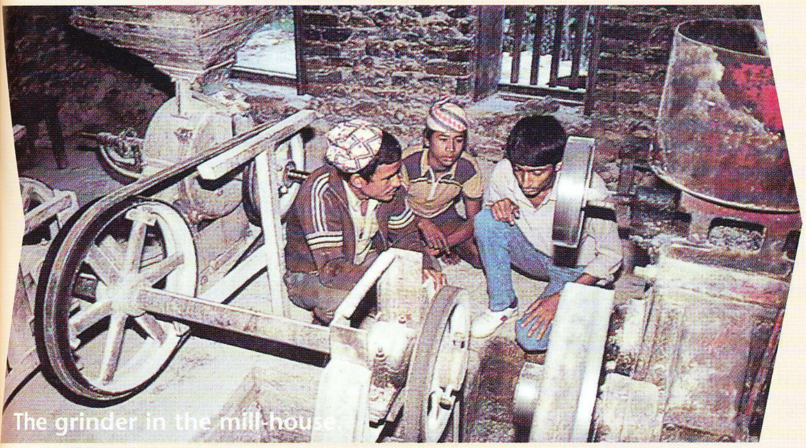

Light comes from a single kerosene lamp.

Figure 18.29
Practical Action's work in Nepal

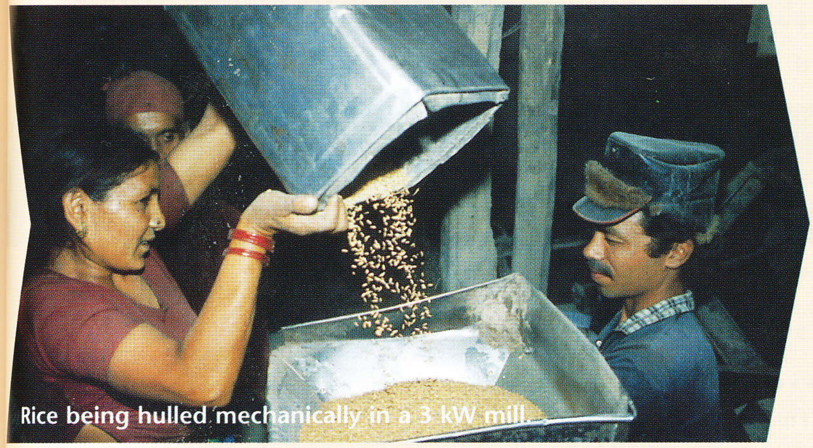
Power for life



The grinder in the mill-house.

Grinding enough corn to feed a family for just 3 days takes 15 hours when it is done by hand.

By taking corn to the grinder in the mill-house – usually a popular meeting place for villagers – 3 days' worth of corn can be ground in just 15 minutes.

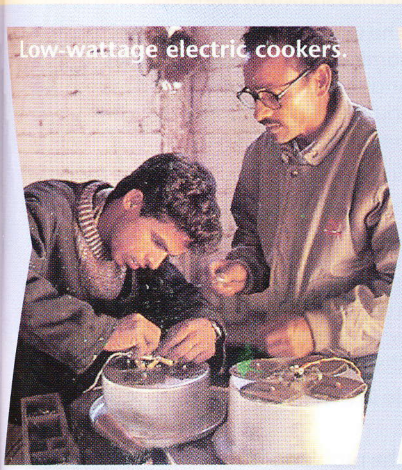


Rice being hulled mechanically in a 3 kW mill.

For thousands of women, the supply of power releases them from the many labour-intensive and time-consuming tasks they previously had to carry out by hand.

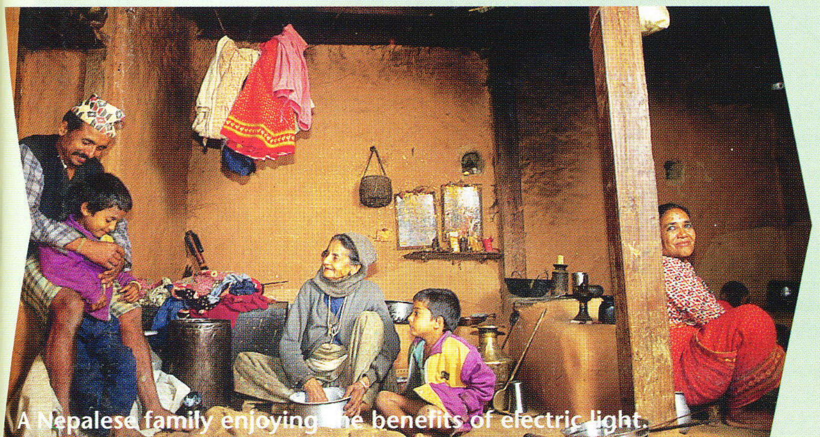
Villagers can now hull their rice mechanically with this 3 kW mill, driven by a micro-hydro turbine. Time is saved and quality and productivity increased.

Low-wattage electric cookers.



Cooking on an open fire burns up a great deal of wood (which is becoming increasingly scarce) and gives off a lot of thick smoke. As a result, the villagers not only have to walk long distances to collect their fuel, but many women and children suffer from serious lung disorders.

Practical Action is helping to develop two low-wattage electric cookers which have been specifically designed to make use of 'off-peak' electricity. The *bijuli dekchi* heats water during off-peak times for use in cooking later on, while the heat storage cooker stores the energy available during off-peak periods and releases it at mealtimes for cooking. Both save fuelwood and help to reduce deforestation.



A Nepalese family enjoying the benefits of electric light.

Kerosene lamps are costly to run, and those who can afford them have to collect fuel in cans from towns which are usually several days' walk away.

With electric light, children and adults can improve their education by learning to read and write in the evenings. Electric light is also cheaper, cleaner and brighter than kerosene.

Further reference

Blades, H. (2007) 'Canada's black gold', *Geography Review* Vol 20 No 3 (January).

Clark, N.A. (2006) *Tidal Barrages and Birds*, Ibis.

Middleton, N.J. (2008) *The Global Casino: An Introduction to Environmental Issues*, Hodder Arnold.

Patterson, W. (2007) *Keeping the Lights On: towards sustainable electricity*, Earthscan.

Pickering, K.T. and Owen, L.A. (1997) *An Introduction to Global Environmental Issues*, Routledge.

Sinden, G. (2007) 'Wind power', *Geography Review* Vol 21 No 1 (September).

BP Amoco Statistical Review of World Energy:
www.bp.com/productlanding.do?categoryId=6929&contentId=7044622

British Wind Energy Association:
www.bwea.com

Energy consumption:
www.un.org/Pubs/CyberSchoolBus/index.shtml

www.worldenergy.org

International Atomic Energy Agency (IAEA):
www.iaea.org/

International Energy Agency (IEA), World Energy Outlook:
www.worldenergyoutlook.org/

Renewable energy:
www.berr/gov.uk/energy/index.html

www.bbc.co.uk/climate/adaptation/renewable_energy.shtml

UK Energy policies and statistics:
www.berr.gov.uk/whatwedo/energy/index.html

US Department of Energy's Efficiency and Renewable Energy Network:
www.eere.energy.gov/

US Energy Information Administration:
www.eia.doe.gov/

World Commission on Dams:
www.dams.org/

World Energy Council:
www.worldenergy.org/

Questions & Activities

Activities

1 a i What are 'natural resources'? *(1 mark)*

ii What is the difference between renewable and non-renewable resources? *(2 marks)*

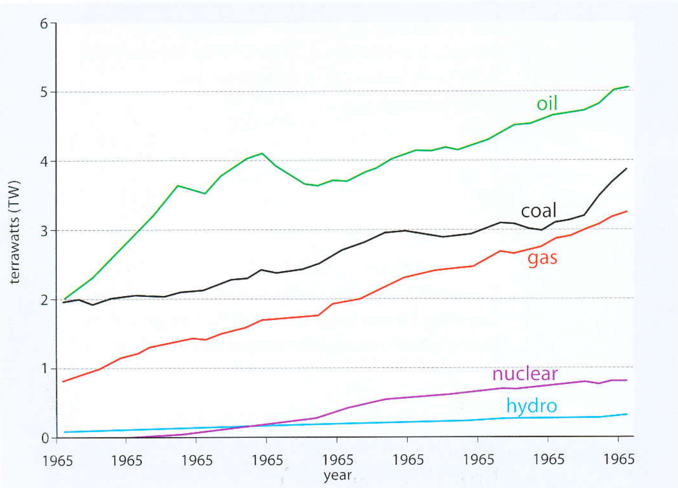
iii Name a renewable source of energy that is used commercially. State where it is produced and explain why conditions in that area are suitable. *(3 marks)*

iv Explain what will happen to the amount of reserves of a fuel such as natural gas if:

- the market price of gas goes up
- new technology is developed, allowing deeper wells to be drilled. *(4 marks)*

Figure 18.30

Rate of world energy usage in terawatts (TW)



b Study Figure 18.30.

i Describe the main trends shown by the graph. *(4 marks)*

ii During the 1990s the use of energy resources by the more economically developed countries did not increase, and may even have fallen. At the same time the amount used by less economically developed countries increased.

Explain this situation. *(4 marks)*

c Describe the main features of the world trade in any one fuel. *(7 marks)*

2 a Fuelwood is an important source of power in many remote regions in less economically developed countries (LEDCs). Name an example of a region where fuelwood is widely used and:

i explain why people in that region rely on fuelwood. *(3 marks)*

ii describe some of the problems caused for the economy and the environment by the reliance on fuelwood. *(5 marks)*

b Large hydro-electric power schemes are seen as the solution to the energy shortages of many LEDCs.

i Suggest why some people see such schemes as a welcome development for that country. *(5 marks)*

ii Suggest why other people see such schemes as being unwelcome. *(5 marks)*

c Recent conferences on global warming have concluded that more economically developed countries should share their technological knowledge with the LEDCs. How might such sharing help to reduce global warming in future? *(7 marks)*

Exam practice: basic structured questions

3 a In many less economically developed countries fuelwood is the main source of energy for heating and cooking. Explain how this can cause:

i damage to the environment

ii social problems. *(10 marks)*

b i What does 'appropriate technology' mean? *(2 marks)*

ii Appropriate technology can be used by poor people in remote areas to harness energy supplies. Describe one such scheme in a named region of the world. *(5 marks)*

iii Explain how the scheme described in **b ii** brings social and economic benefits to the people who use it. *(8 marks)*

4 a What is meant by the term 'fossil fuel'? *(2 marks)*

b Choose **one** country that has important reserves of coal.

i Describe the distribution of coal reserves in that country. *(4 marks)*

ii Explain the economic factors that are influencing decisions about whether those reserves should be exploited at the present time. *(9 marks)*

iii Name **one** environmental problem caused by the use of coal as a fuel. Describe the problem. Explain how good management can reduce the problem. *(10 marks)*

Exam practice: structured questions

5 Lack of a suitable power supply is holding back development in many remote areas of the world. For a named area:

a explain how shortage of power has caused economic and social problems. *(12 marks)*

b explain how the problems are being reduced by provision of an appropriate power supply. *(13 marks)*

6 Study Figure 18.31a.

a i Describe the major changes in the UK's energy mix between 1971 and 2005. *(5 marks)*

ii Account for the decline in the use of coal and the increase in the use of natural gas over this period. *(10 marks)*

b Should the UK increase its use of nuclear energy over the next 10 years?

Justify your answer. *(10 marks)*

7 Study the two graphs in Figure 18.31.

a Describe the major changes in France's energy supply between 1971 and 2005. *(6 marks)*

b Compare France's energy mix in 2005 with the energy mix of the UK. *(4 marks)*

c Which of the two countries has the better mix in terms of:

- energy security
- minimising environmental damage?

Justify your answer. *(15 marks)*

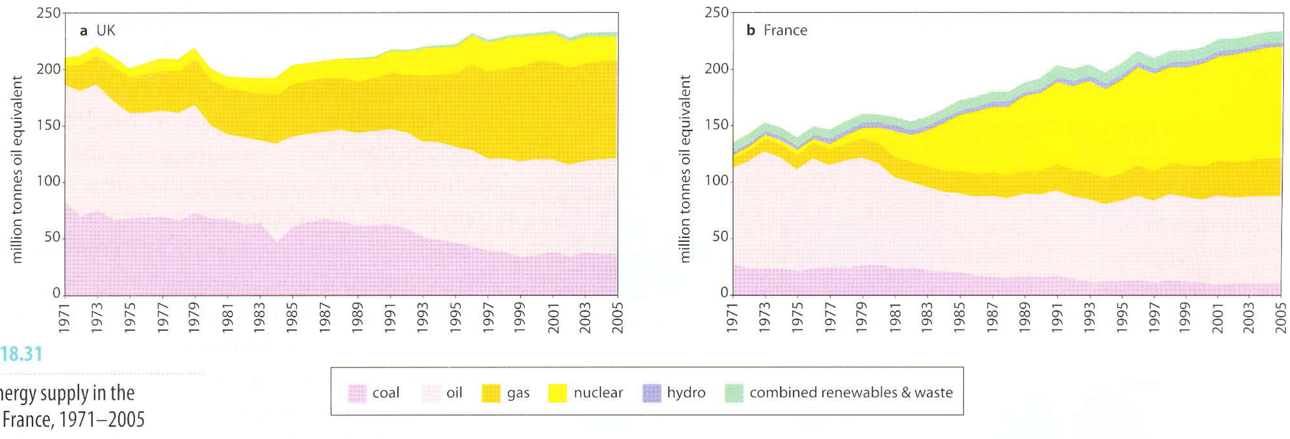


Figure 18.31

Total energy supply in the UK and France, 1971–2005

Exam practice: essays

8 Evaluate the arguments for and against the development of new coal-fired power stations, such as the one that is proposed at Kingsnorth. *(25 marks)*

9 Discuss the benefits and problems that would be involved in an increased reliance on biomass as a major source of energy supply. *(25 marks)*

10 Choose any **two** of the following sources of renewable energy.

- wind
- solar
- waves
- tidal power
- geothermal

Discuss the economic, environmental and technological issues that are involved in the development of each of your chosen sources. *(25 marks)*