12 Environmental management

12.1 Sustainable energy supplies

Renewable and non-renewable energy

Non-renewable sources of energy are the fossil fuels (Figure 12.1) and nuclear fuel. These are finite, so as they are used up the supply that remains is reduced. Eventually, these non-renewable resources could become completely exhausted. Renewable energy can be used over and over again. The sources of renewable energy are mainly forces of nature that are sustainable and that usually cause little or no environmental pollution. Renewable energy includes hydro-electric (HEP), biomass, wind, solar, geothermal, tidal and wave power.

Energy resources are at the core of the global economy. Energy is vital for economic growth and development. However, emissions of greenhouse gases from energy use are the main contributors to human-induced climate change. Energy production and consumption are major issues both within and between countries. Many countries that have to import a significant amount of the energy they use have become more and more concerned about energy security. There are growing concerns in some parts of the world that an inequitable availability and uneven distributions of energy sources may lead to conflict.

Figure 12.1 An oil well in Dorset, UK

Energy shortages have occurred in different parts of the world on a number of occasions in the past. Such shortages can have major economic and social consequences. But it is not just potential shortages of energy that is the concern. In poor countries, energy poverty has a major impact on people's lives and it is a major obstacle to development. The concept of fuel poverty is becoming a more and more important issue in many apparently affluent countries as people struggle to pay for rising energy bills in harsh winters.

At present, non-renewable resources dominate global energy. The environmental challenge is to transform the global energy mix to achieve a better balance between renewables and non-renewables. The key energy issues for individual countries are the three Ss: sustainability, security and strategy.

Factors affecting the demand for and supply of energy

At the national scale, there are huge variations in energy demand and supply. Demand is primarily governed by the size of a country's population and its level of economic development. The gap between the world's richest and poorest countries in terms of energy demand is huge. Growth in energy demand is particularly rapid in middle-income countries (MICs) such as China and India. A country's energy policy can have a significant impact on demand if it focuses on efficiency and sustainability as opposed to concentrating solely on building more power stations and refining facilities. High levels of pollution due to energy consumption can be a strong stimulus to developing a cleaner energy policy.

As might be expected, global variations in energy supply occur for a number of reasons. These can be broadly subdivided into physical, economic and political factors. Table 12.1 shows examples for each of these groupings. The combination of factors operating in each country can vary significantly.

Table 12.1 Factors affecting the supply of energy

Physical	Economic	Political
• Deposits of fossil fuels are only found in a limited number of locations. • Large-scale HEP development requires high precipitation, major steep-sided valleys and impermeable rock. • Large power stations require flat land and geologically stable foundations. • Solar power needs a large number of days a year with strong sunlight. • Wind power needs high average wind speeds throughout the year. • Tidal power stations require a very large tidal range. • The availability of biomass varies widely according to climatic conditions.	• The most accessible, and lowest-cost, deposits of fossil fuels are invariably developed first. • Onshore deposits of oil and gas are usually cheaper to develop than offshore deposits. • Potential HEP sites close to major transport routes and existing electricity transmission corridors are more economical to build than those in very inaccessible locations. • In poor countries, FDI is often essential for the development of energy resources. • When energy prices rise significantly, companies increase spending on exploration and development.	• Countries wanting to develop nuclear electricity require permission from the International Atomic Energy Agency. • International agreements such as the Kyoto Protocol can have a considerable influence on the energy decisions of individual countries. • Potential HEP schemes on 'international rivers' may require the agreement of other countries that share the river. • Governments may insist on energy companies producing a certain proportion of their energy from renewable sources. • Legislation regarding emissions from power stations will favour the use of, for example, low-sulphur coal, as opposed to coal with a high sulphur content.

The key factor in supply is energy resource endowment. Some countries are relatively rich in domestic energy resources, while others are lacking in such resources and heavily reliant on imports. However, resources by themselves do not constitute supply. Capital and technology are required to exploit resources.

The use of energy in all countries has changed over time due to a number of factors:

- **Technological development** – for example: **a** nuclear electricity has only been available since 1954, **b** oil and gas can now be extracted from much deeper waters than in the past and **c** renewable energy technology is advancing steadily.
- **Increasing national wealth** – as average incomes increase living standards improve, which involves the increasing use of energy and the use of a greater variety of energy sources.
- **Changes in demand** – at one time, all of Britain's trains were powered by coal and most people also used coal for heating in their homes. Before natural gas was discovered in the North Sea, Britain's gas was produced from coal (coal gas).
- **Changes in price** – the relative prices of the different types of energy can influence demand. Electricity production in the UK has been switching from coal to gas over the last 20 years, mainly because power stations are cheaper to run on natural gas.
- **Environmental factors/public opinion** – public opinion can influence decisions made by governments. People today are much better informed about the environmental impact of energy sources than they were in the past.

Section 12.1 Activities

1 Look at Table 12.1. Select two points from each of the three categories to investigate further. Present your findings to others in your class.

2 For the UK, find out when:
   a the last steam trains (burning coal) stopped being used on Britain's general railway network
   b nuclear electricity first came online
   c North Sea gas first came online.

Trends in consumption of conventional energy resources

The fossil fuels dominate the global energy situation. Their relative contributions (for 2012) are:

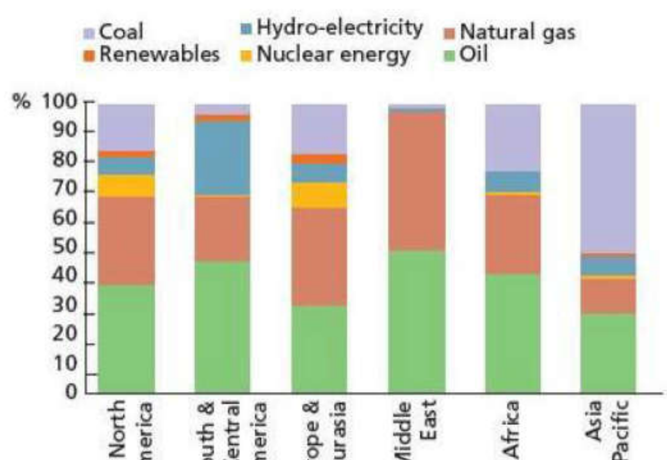
- **oil**: 33 per cent (Figure 12.2)
- **coal**: 30 per cent
- **natural gas**: 24 per cent.

Figure 12.2 Oil refinery, Milford Haven, UK

In contrast, HEP accounted for 6.6 per cent and nuclear energy 4.5 per cent of global energy. The main data source used in this topic is the *BP Statistical Review of World Energy*. It includes commercially traded fuels only. It excludes fuels such as wood, peat and animal waste, which, though important in many countries, are unreliably documented in terms of production and consumption statistics.

Figure 12.3 shows the regional pattern of energy consumption for 2012. Consumption by type of fuel varies widely by world region:

- **Oil** – only in Asia Pacific is the contribution of oil less than 30 per cent and it is the main source of energy in four of the six regions shown in Figure 12.3. In the Middle East, it accounts for approximately 50 per cent of consumption.
- **Coal** – only in the Asia Pacific region is coal the main source of energy. In contrast, it accounts for less than 5 per cent of consumption in South and Central America, and in the Middle East. China was responsible for 50.2 per cent of global coal consumption in 2012.
- **Natural gas** – natural gas is the main source of energy in Europe and Eurasia and it is a close second to oil in the Middle East. Its lowest share of the energy mix is 11 per cent in the Asia Pacific region.
- **Hydro-electricity** – the relative importance of hydro-electricity is greatest in South and Central America (25 per cent). Elsewhere, its contribution varies from 6 per cent in Africa to less than 1 per cent in the Middle East.
- **Nuclear energy** – nuclear energy is not presently available in the Middle East and it makes the smallest contribution of the five traditional energy sources in Asia Pacific, Africa and South and Central America. It is most important in Europe and Eurasia and North America.
- **Renewables** – consumption of renewable energy other than HEP is rising rapidly, but from a very low base. Renewables make the largest relative contribution to energy consumption in Europe and Eurasia.



Source: *IGCSE Geography* 2nd edition, P. Guinness & G. Nagle (Hodder Education, 2014) p.208

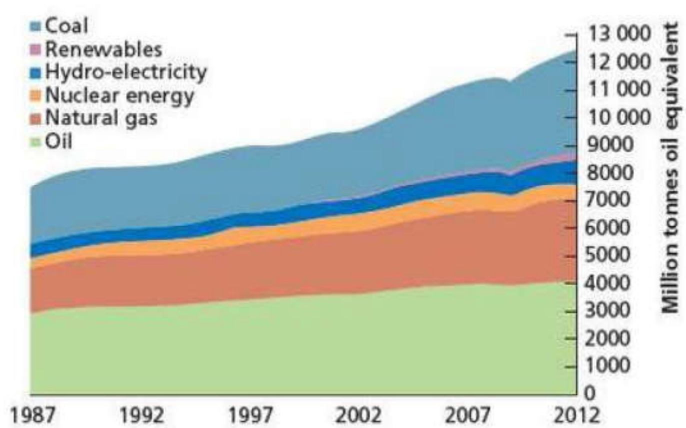
Figure 12.3 The regional pattern of energy consumption, 2012

In terms of usage by type of energy, some general points can be made:

The most developed countries tend to use a wide mix of energy sources, being able both to invest in domestic energy potential and to buy energy from abroad.

- The high investment required for nuclear electricity means that only a limited number of countries produce electricity this way. However, many countries that could afford the investment choose not to adopt this strategy.
- Richer nations have been able to invest more money in renewable sources of energy.
- In the poorest countries, **fuelwood** is an important source of energy, particularly where communities have no access to electricity.

Figure 12.4 shows how global consumption of the five major traditional sources of energy changed between 1987 and 2012. The demand for energy has grown relentlessly over this time period, with an overall increase of 60 per cent in total global energy consumption.



Source: *IGCSE Geography* 2nd edition, P. Guinness & G. Nagle (Hodder Education, 2014) p.207

Figure 12.4 Global consumption of major energy sources, 1987–2012

Figure 12.5 shows per person energy consumption around the world. The highest consumption countries such as the USA and Canada use more than 6 tonnes oil equivalent per person, while almost all of Africa and much of Latin America and Asia use less than 1.5 tonnes oil equivalent per person. The individual countries consuming the most energy in 2012, as a percentage of the world total, were:

- **China**: 21.9 per cent
- **USA**: 17.7 per cent
- **Russia**: 5.6 per cent
- **India**: 4.8 per cent
- **Japan**: 3.8 per cent.

Source: *IGCSE Geography* 2nd edition, P. Guinness & G. Nagle (Hodder Education, 2014) p.209

Figure 12.5 World map showing energy consumption per person, 2012

Wealth is the main factor explaining the energy gap. The use of energy can improve the quality of people's lives in so many ways. That is why most people who can afford to buy cars, televisions and washing machines do so. However, there are other influencing factors, with climate at the top of the list.

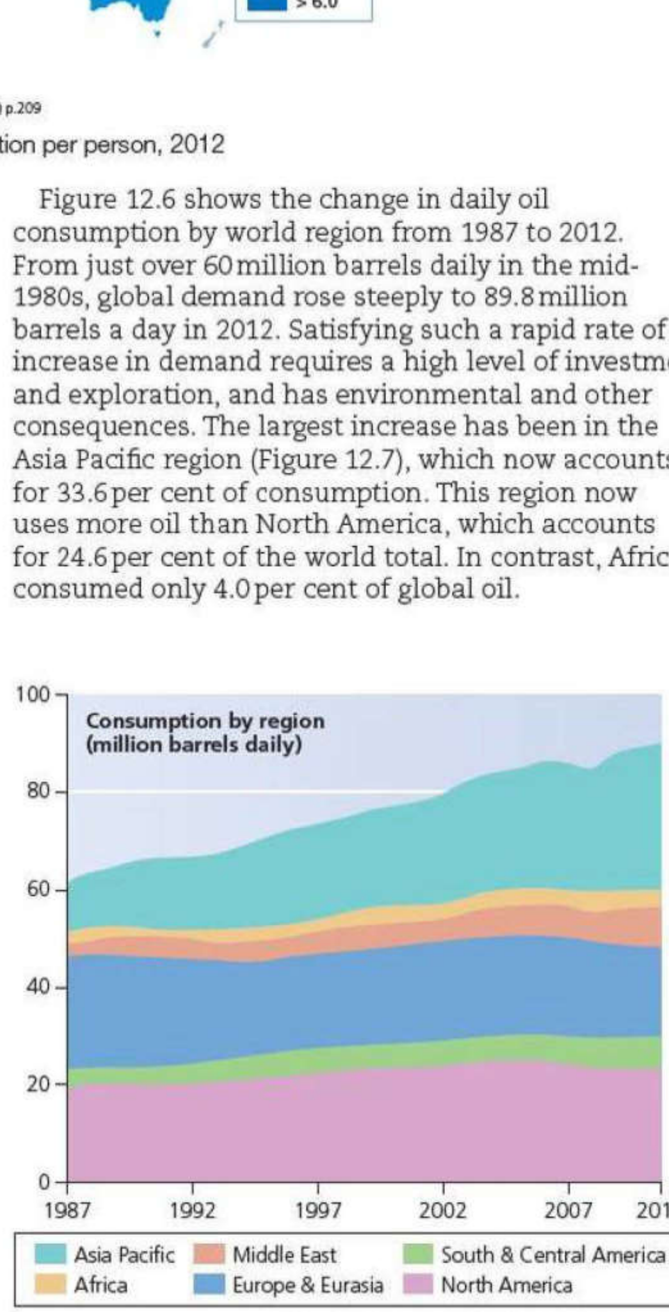
Oil: global patterns and trends

Oil is the most important of the non-renewable sources of energy. Even though investment in new sources of energy is increasing rapidly, the global economy still relies on oil to a considerable extent. Oil clearly has significant advantages as a source of energy, otherwise it would not be as important as it is today. However, its disadvantages have gained increasing recognition in recent decades (Table 12.2).

Table 12.2 The advantages and disadvantages of oil

Advantages	Disadvantages
• A compact, portable source of energy; relatively easy to transport and store • Used for most forms of mechanical transportation • Flexible use – can be distilled into different fuel products • Cleaner and easier to burn than coal • Compared to most other fuel sources, it remains one of the most economical sources of energy • The oil industry has been the source of much advanced technology • Oil refining produces the world's supply of elemental sulphur as a by-product, used for many industrial applications • Has a well-established global infrastructure	• Non-renewable – takes millions of years to form • Burning oil generates CO_2, a greenhouse gas • Oil contains sulphur, which when burnt forms sulphur dioxide and sulphur trioxide; these combine with atmospheric moisture to form sulphuric acid, leading to 'acid rain' • Not as clean or efficient in use as natural gas • Serious oil spills from supertankers and pipelines • Locating additional reserves requires a very high level of investment • Political instability of some major oil producing countries and concern about the vulnerability of energy pathways • Concerns that 'peak oil' is not far away • The price of oil has varied significantly over the last decade • Some oil is now being strip-mined in the form of tar sands, creating serious environmental concerns

Figure 12.6 shows the change in daily oil consumption by world region from 1987 to 2012. From just over 60 million barrels daily in the mid-1980s, global demand rose steeply to 89.8 million barrels a day in 2012. Satisfying such a rapid rate of increase in demand requires a high level of investment and exploration, and has environmental and other consequences. The largest increase has been in the Asia Pacific region (Figure 12.7), which now accounts for 33.6 per cent of consumption. This region now uses more oil than North America, which accounts for 24.6 per cent of the world total. In contrast, Africa consumed only 4.0 per cent of global oil.



Source: *BP Statistical Review of World Energy 2013*, p.12

Figure 12.6 Oil consumption by world region, 1987–2012

Figure 12.7 Fuel station on the Mekong River, Vietnam

In 2012, the Middle East accounted for over 48 per cent of global proven reserves. Political instability in the Middle East is a major concern to the countries that import oil from this region. Table 12.3 shows the reserves-to-production ratio for the world in 2012. While the R/P ratio is over 78 years in the Middle East and even higher in South and Central America, it is only 13.6 years in Asia Pacific.

Table 12.3 Oil reserves-to-production ratio at the end of 2012

Region	Reserves/production ratio (years)
North America	38.7
South and Central America	123.0
Europe and Eurasia	22.4
Middle East	78.1
Africa	37.7
Asia Pacific	13.6
World	**52.9**

Source: BP Statistical Review of World Energy 2013

The price of oil increased sharply in the early years of the new century, causing major financial problems in many importing countries. It rose from $10 a barrel in 1998 to more than $130 a barrel in 2008, before falling back sharply in the global recession of 2008–09. As the global economy has slowly recovered, the price of oil has fluctuated considerably and was at a price of about $40 a barrel in late 2015.

When will global peak oil production occur?

There has been growing concern about when global oil production will peak and how fast it will decline thereafter. There are concerns that there are not enough large-scale projects underway to offset declining production in well-established oil-production areas. The rate of major new oil-field discoveries has fallen sharply in recent years. It takes 6 years on average from first discovery for a very large-scale project to start producing oil. In 2010, the International Energy Agency expected peak oil production somewhere between 2013 and 2037, with a fall by 3 per cent a year after the peak. The United States Geological Survey predicted that the peak was 50 years or more away.

However, in complete contrast, the Association for the Study of Peak Oil and Gas (ASPO) predicted in 2008 that the peak of global oil production could come as early as 2011, stating 'Fifty years ago the world was consuming 4 billion barrels of oil per year and the average discovery was around 30 billion. Today we consume 30 billion barrels per year and the discovery rate is now approaching 4 billion barrels of crude oil per year'. ASPO's dire warnings have not (yet) materialised. This is at least partly down to new developments, particularly the rapid growth in production of shale oil and gas in the USA, which has changed the global energy situation. The current period of slow growth in the global economy has also eased the pressure on energy resources.

Shale oil

The exploitation of shale oil has been a very recent development. It has been concentrated mainly in the United States. Shale oil is extracted from reserves, sometimes described as 'tight oil' reserves, held in shales and other rock formations from which it will not naturally flow freely. Shale oil has become more accessible due to advances in technology.

The rapid increase in the scale of production in the USA has fundamentally changed global energy markets as the USA has quickly regained much of its self-sufficiency in energy. Gas can also be obtained from shale, and the exploitation of shale gas has led the exploitation of shale oil by a few years. The exploitation of shale deposits has had a massive impact on US gas and oil production in recent years. Further significant production increases of shale oil and gas are forecast for the USA, and the 'shale revolution' is likely to spread to other parts of the world, albeit with a time lag. The speed of this geographical spread (diffusion) will depend on a number of factors, including the extent of opposition to this process on environmental grounds.

Although the basic technology was originally developed in the USA in the 1940s, the recent 'shale revolution' was the result of technological breakthroughs in horizontal drilling and hydraulic fracturing (fracking), which have made shale deposits economically viable. In the USA, oil production peaked in 1970 at 534 million tonnes, falling to 305 million tonnes in 2008. The subsequent rise to 499 million tonnes in 2013 has been a phenomenal turnaround. Most of this increase has been due to the rapid rise in the production of shale oil. The full extent of recoverable shale oil in the USA is still to be determined as exploration continues. A recent analysis by the EIA put the total at nearly 8 billion tonnes, a very considerable energy resource base indeed!

The geopolitical impact of changes in patterns and trends in oil

Energy security depends on resource availability – domestic and foreign – and security of supply. It can be affected by geopolitics, and is a key issue for many economies. Because there is little excess capacity to ease pressure on energy resources, energy insecurity is rising, particularly for non-renewable resources.

The USA, gravely concerned about the political leverage associated with imported oil, began in 1977 the construction of a strategic petroleum reserve. The oil was to be stored in a string of salt domes and abandoned salt mines in southern Louisiana and Texas, which could be linked up easily to pipelines and shipping routes. The initial aim was to store 1billion barrels of oil that could be used in the event of supply discontinuation. The SPR currently holds 700million barrels.

The Middle East is the major global focal point of oil exports. The long-running tensions that exist in the Middle East have at times caused serious concerns about the vulnerability of oilfields, pipelines and oil-tanker routes. The destruction of oil wells and pipelines during the Iraq War showed all too clearly how energy supplies can be disrupted. Middle East oil exports are vital for the functioning of the global economy. Most Middle East oil exports go by tanker through the Strait of Hormuz, a relatively narrow body of water between the Persian Gulf and the Gulf of Oman. The strait at its narrowest is 55kilometres wide. Roughly 30per cent of the world's oil supply passes through the Strait, making it one of the world's strategically important chokepoints. Iran has at times indicated that it could block this vital shipping route in the event of serious political tension. This could cause huge supply problems for many importing countries. Concerns about other key energy pathways have also arisen from time to time.

Section 12.1 Activities

1 Explain why the locations of global oil production and consumption vary so widely.
2 Define the term *reserves-to-production ratio*. Describe how this varies around the world.
3 a Why is the prediction of peak oil production so important?
  b Suggest why the predictions of when peak oil production will occur vary so widely.

Natural gas

Global production of natural gas increased from 2524billion m^3 in 2002 to 3364billion m^3 in 2012 (Table 12.4). All six world regions showed an increase in production. However, the largest producing world regions, Europe/Eurasia and North America, recorded the lowest percentage increases between 2002 and 2012. The highest relative change was in the Middle East.

Table 12.4 Natural gas production by world region, 2002–12

Region	2002	2012	% change
North America	763.6	896.4	17
South & Central America	107.9	177.3	64
Europe & Eurasia	966.5	1035.4	7
Middle East	247.2	548.4	122
Africa	138.2	216.2	56
Asia Pacific	300.5	490.2	63
Total world	**2523.9**	**3363.9**	**33**

Source: BP Statistical Review of World Energy 2013

On an individual country basis, natural gas production is dominated by the USA (20.4per cent of the global total) and the Russian Federation (17.6per cent). There is a very substantial gap between these two natural gas giants and the next largest producers, which are Iran (4.8per cent), Qatar (4.7per cent) and Canada (4.6per cent).

There is a much stronger correlation between consumption and production of natural gas than for oil, due mainly to the different ways these two energy products are transported. Global consumption of natural gas in 2012 was led by Europe and Eurasia (32.6per cent), North America (27.5per cent) and Asia Pacific (18.8per cent).

During the period 2002–12, proven reserves of natural gas increased substantially. The global share of proven reserves in the Middle East fell slightly, while the share held in Europe and Eurasia increased. On an individual country basis, the largest reserves in 2012 were in Iran (18per cent), the Russian Federation (17. 6per cent) and Qatar (13.4per cent). In 2012, the global reserves-to-production ratio stood at 55.7years.

Coal

Coal production is dominated by the Asia Pacific region, accounting for 67.8per cent of the global total in 2012. Much of this coal is produced in China, which alone mines 47.5per cent of the world total. The next largest producing countries were the USA (13.4per cent), Australia (6.3per cent), Indonesia (6.2per cent), India (6.0per cent) and the Russian Federation (4.4per cent). Like natural gas, there is a strong relationship between the production and consumption of coal by world region. Consumption is led by Asia Pacific (69.9per cent), Europe and Eurasia (13.9per cent) and North America (12.6per cent). China alone consumed 50.2per cent of world coal in 2012.

Figure 12.8 shows the proven reserves of coal in 2002 and 2012. There is a fairly even spread between three regions: Europe/Eurasia, Asia Pacific and North America. However, total global reserves declined by 12.5per cent over this ten-year time period. In terms of the reserves-to-production ratio (Figure 12.9), the figure for Asia Pacific at 51years is significantly below that for other world regions. The global reserves-to-production ratio fell from 119years in 2009 to 109years in 2012, a significant decline in such

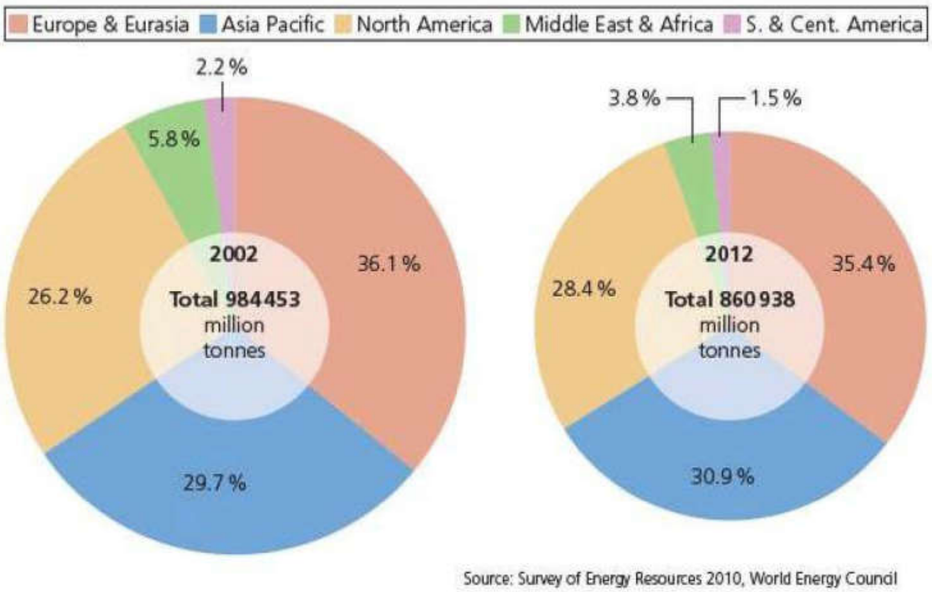


Figure 12.8 Distribution of proven coal reserves, 2002 and 2012

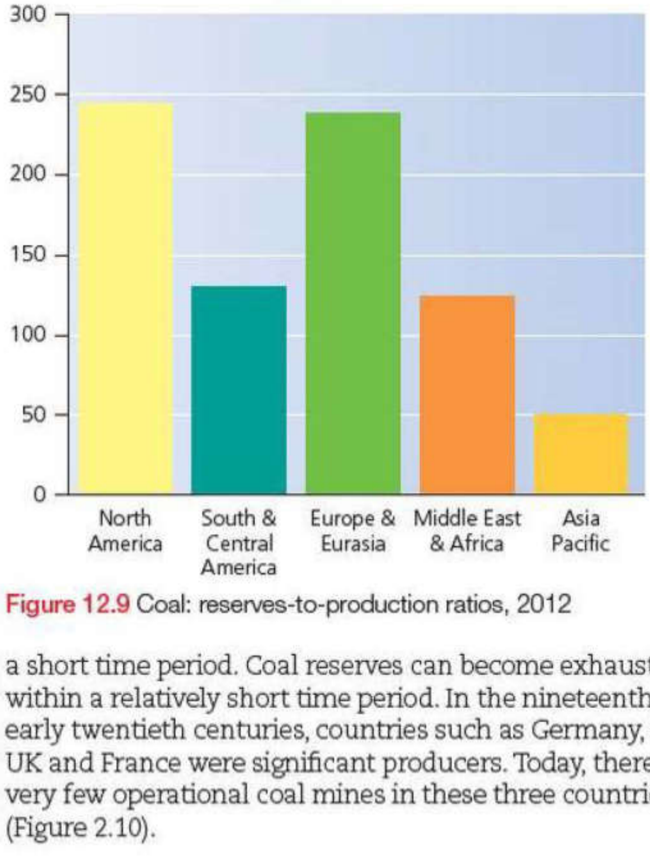


Figure 12.9 Coal: reserves-to-production ratios, 2012

Figure 12.10 A former coal mine in the Massif Central region of France, which was closed in the early 1990s – it is now a museum to the coal industry

a short time period. Coal reserves can become exhausted within a relatively short time period. In the nineteenth and early twentieth centuries, countries such as Germany, the UK and France were significant producers. Today, there are very few operational coal mines in these three countries (Figure 2.10).

Extending the 'life' of fossil fuels

There are a number of technologies that can improve the use and prolong the life of fossil fuels. These include coal gasification, clean coal technologies and the extraction of unconventional natural gas. Such techniques may be very important in buying time for more renewable energy to come online.

Coal gasification is the technology that could transform the situation. At present, electricity from coal gasification is more expensive than that from traditional power plants, but if more stringent pollution laws are passed in the future this situation could change significantly.

The coal industry in a number of areas may be on the point of a limited comeback, with the development of **clean coal technology**. This new technology has developed forms of coal that burn with greater efficiency and capture coal's pollutants before they are emitted into the atmosphere. The latest 'supercritical' coal-fired power stations, operating at higher pressures and temperatures than their predecessors, can operate at efficiency levels 20 per cent above those of coal-fired power stations constructed in the 1960s. Existing power stations can be upgraded to use clean coal technology.

Conventional natural gas, which is generally found within a few thousand metres or so of the surface of the Earth, has accounted for most of the global supply to date. However, in recent years 'unconventional' deposits have begun to contribute more to supply. The main categories of **unconventional natural gas** are:

- deep gas
- tight gas
- gas-containing shales
- coalbed methane
- geopressurised zones
- Arctic and sub-sea hydrates.

Unconventional deposits are clearly more costly to extract but as energy prices rise and technology advances, more and more of these deposits are attracting the interest of governments and energy companies.

Nuclear power: a global renaissance?

Until a few years ago, the future of nuclear power looked bleak, with a number of countries apparently 'running down' their nuclear power stations and many other nations firmly set against the idea of introducing nuclear electricity. However, heightened fears about oil supplies, energy security and climate change have brought this controversial source of power back onto the global energy agenda.

No other source of energy creates such heated discussion as nuclear power. The main concerns about nuclear power are:

- power plant accidents, which could release radiation into air, land and sea
- radioactive waste storage/disposal – no country has yet implemented a long-term solution to the nuclear-waste problem
- rogue state or terrorist use of nuclear fuel for weapons
- high construction and decommissioning costs
- the possible increase in certain types of cancer near nuclear plants.

In addition, because of the genuine risks associated with nuclear power and the level of security required, it is seen by some people as less 'democratic' than other sources of power.

By early 2015, 30 countries around the world were operating 443 nuclear reactors for electricity generation, with 66 new nuclear plants under construction. Nuclear power accounted for almost 11 per cent of the world's electricity production in 2012.

With 99 operating reactors, the USA leads the world in the use of nuclear electricity. This amounts to 32.7 per cent of the world's total , producing about 20 per cent of the USA's electricity. At one time, the rise of nuclear power looked unstoppable. However, a serious incident at the Three Mile Island nuclear power plant in Pennsylvania in 1979, and the much more serious Chernobyl disaster in Ukraine in 1986, brought any growth in the industry to a virtual halt. No new nuclear power plants have been ordered in the USA since then, although public opinion has become more favourable in recent years, as memories of the Three Mile Island and Chernobyl incidents recede into the past, and as worries about polluting fossil fuels increase.

The big advantages of nuclear power are:

- there are zero emissions of greenhouse gases – this has become increasingly important as concerns about climate change have increased
- it means reduced reliance on imported fossil fuels (which can help ease concerns about energy security)
- it is not as vulnerable to fuel price fluctuations as oil and gas – uranium, the fuel for nuclear plants, is relatively plentiful and most of the main uranium mines are in politically stable countries
- nuclear power plants have demonstrated a very high level of reliability and efficiency in recent years.

The next major consumers of nuclear energy after the USA are France (17.2 per cent of the 2012 world total), Russia (7.2 per cent) and South Korea (6.1 per cent). France obtains over 75 per cent of its electricity from nuclear. Table 12.5 shows all the countries where nuclear power accounts for more than 30 per cent of electricity production. Global nuclear power production declined slightly between 2002 and 2012, from 185.8 million tonnes oil equivalent to 183.2 million tonnes. The current decade will be crucial to the future of nuclear energy, with many countries making final decisions to extend or begin their nuclear electricity capability.

Table 12.5 The contribution of nuclear power to electricity production

Country	Contribution of nuclear power (%)
France	76.9
Slovakia	56.8
Hungary	53.6
Ukraine	49.4
Belgium	47.5
Sweden	41.5
Switzerland	37.9
Slovenia	37.2
Czech Republic	35.8
Finland	34.6
Bulgaria	31.8
Armenia	30.7
South Korea	30.4

A few countries have developed **fast breeder reactor** technology. These reactors are very efficient at manufacturing plutonium fuel from their original uranium fuel load. This greatly increases energy production – but it could prove disastrous should the plutonium get into the wrong hands, as plutonium is the key ingredient for nuclear weapons.

Section 12.1 Activities

1. Compare the changes in production of the five traditional forms of energy between 2002 and 2012.
2. Using Table 12.4, describe how the global production of natural gas changed between 2002 and 2012.
3. Outline the extent of the world's coal reserves.
4. What are the main advantages and disadvantages of nuclear power?

Renewable energy resources

Table 12.6 compares renewable energy capacity at the beginning of 2004 to the end of 2013. For both years, hydro-electricity dominated renewable energy production, but most other sources of renewable energy have grown at a faster rate. Overall renewable power capacity almost doubled in the time period covered by Table 12.6. The newer sources of renewable energy making the largest contribution to global energy supply are wind power and biofuels.

Table 12.6 Capacity of renewable energy sources 2004 and 2013

		Start 2004	End 2013
Investment			
New investment (annual) in renewable power and fuels	Billion US$	39.5	214.4
Power			
Renewable power capacity (total, not including hydro)	gigawatts	85	560
Renewable power capacity (total, including hydro)	gigawatts	800	1560
Hydropower capacity (total)	gigawatts	715	1000
Bio-power capacity	gigawatts	<36	88
Bio-power generation	tera watt hours	227	405
Geothermal power capacity	gigawatts	8.9	12
Solar PV capacity (total)	gigawatts	2.6	139
Concentrating solar thermal power (total)	gigawatts	0.4	3.4
Wind power capacity (total)	gigawatts	48	318
Heat			
Solar hot water capacity (total)	gigawatts	98	326
Transport			
Ethanol production (annual)	billion litres	28.5	87.2
Biodiesel production (annual)	billion litres	2.4	26.3

Source: Renewables 2014 Global Status Report

Hydro-electric power

Of the traditional five major sources of energy, HEP is the only one that is renewable. It is by far the most important source of renewable energy. The 'big four' HEP nations of China, Brazil, Canada and the USA account for almost 53 per cent of the global total. However, most of the best HEP locations are already in use, so the scope for more large-scale development is limited. In many countries though, there is scope for small-scale HEP plants to supply local communities. However, global consumption of hydro-electricity increased from 598.5 million tonnes oil equivalent in 2002 to 831.1 million tonnes in 2012.

In 2012, the countries with the largest share of the world total were: China (23.4 per cent), Brazil (11.4 per cent) (Figure 12.11), Canada (10.4 per cent) and the USA (7.6 per cent). Consumption of hydro-electricity in China amounted to 194.8 million tonnes oil equivalent in 2012.

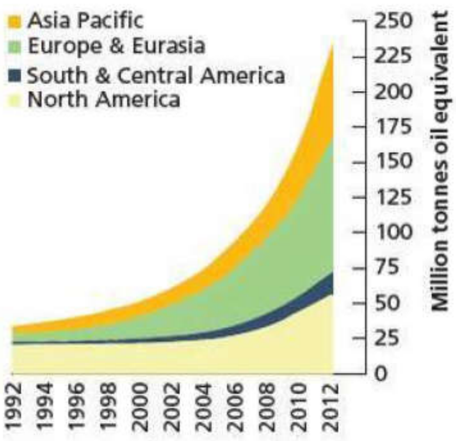
Figure 12.11 Inside the Itaipu hydro-electric power plant, Brazil

Although HEP is generally seen as a clean form of energy, it is not without its problems, which include:

- Large dams and power plants can have a huge negative visual impact on the environment.
- They may obstruct the river for aquatic life.
- There may be a deterioration in water quality.
- Large areas of land may need to be flooded to form the reservoir behind the dam.
- Submerging large forests without prior clearance can release significant quantities of methane, a greenhouse gas.

Newer alternative energy sources

The first major wave of interest in new alternative energy sources resulted from the energy crisis of the early 1970s. However, the relatively low price of oil in the 1980s, 1990s and the opening years of the present century dampened down interest in these energy sources. Then, renewed concerns about energy in recent years and corresponding price increases kick-started the alternative-energy industry again. The main drawback to the new alternative energy sources is that they invariably produce higher cost electricity than traditional sources. However, the cost gap with non-renewable energy is narrowing. Figure 12.12 shows the sharp increase in the consumption of renewable energy (other than HEP) in the last decade. In 2012, this accounted for 1.9 per cent of global primary energy consumption. The newer sources of renewable energy making the largest contribution to global energy supply are wind power and biofuels.



Source: *IGCSE Geography* 2nd edition, P. Guinness & G. Nagle (Hodder Education, 2014) p.212

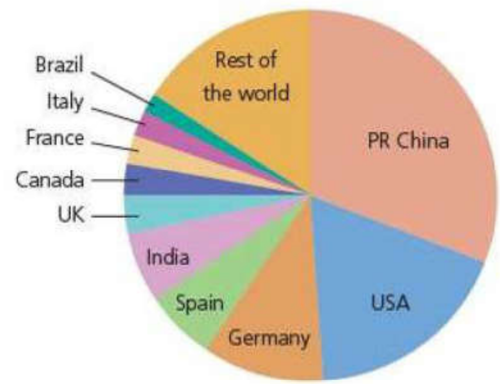
Figure 12.12 Renewable energy consumption by world region, 1992–2012

Figure 12.13 Wind farm in northern Spain

Wind power

Wind power is arguably the most important of the new renewable sources of energy (Fig 12.13). The worldwide capacity of wind energy is approaching 400000 megawatts, a very significant production mark (Figure 12.14). The wind industry set a new record for annual installations in 2014. Global wind energy is dominated by a relatively small number of countries. China is currently the world leader, with 31 per cent of global capacity, followed by the USA, Germany, Spain and India. Together, these five countries account for almost 72 per cent of the global total. In the last five years, for the first time ever, more new wind power capacity was installed in LICs and MICs than in the developed world.

Wind energy has reached the 'take-off' stage, both as a source of energy and a manufacturing industry. As the cost of wind energy improves further against conventional energy sources, more and more countries will expand into this sector. However, projections regarding the industry still vary considerably because of the number of variables that will impact on its future.



Country	Megawatts	Share (%)
PR China	114763	31.1
USA	65879	17.8
Germany	39165	10.6
Spain	22987	6.2
India	22465	6.1
United Kingdom	12440	3.4
Canada	9694	2.6
France	9285	2.5
Italy	8663	2.3
Brazil	5939	1.6
Rest of the world	58275	15.8
Total Top 10	**311279**	**84.2**
World total	**369553**	**100**

Source: GWE

Figure 12.14 Global wind power capacity, end 2014

Costs of generating electricity from wind today are only about 10 per cent of what they were 20 years ago due mainly to advances in turbine technology. Thus, at well-chosen locations, wind power can now compete with conventional sources of energy. Wind energy operators argue that costs should fall further due to **a** further technological advances and **b** increasing economies of scale. One large turbine manufacturer has stated that it expects turbine costs to be reduced by 3.5 per cent a year for the foreseeable future. Table 12.7 summarises the advantages and disadvantages of wind power.

Table 12.7 The advantages and disadvantages of wind power

Advantages	Disadvantages
• A renewable source of energy that can produce reasonable levels of electricity with current technology • Advances in wind turbine technology over the last decade have reduced the cost per unit of energy considerably • Suitable locations with sufficient wind conditions can be found in most countries • Wind energy has reached the take-off stage both as a source of energy and as a manufacturing industry • Flexibility of location with offshore wind farms gaining in popularity • Repowering can increase the capacity of existing wind farms • Significant public support for a renewable source of power although this may be waning to an extent	• Growing concerns about the impact on landscapes as the number of turbines and wind farms increases • NIMBY (not in my back yard) protests with people concerned about the impact of local turbines adversely affecting the value of their properties • The hum of turbines can be disturbing for both people and wildlife • Debate about the number of birds killed by turbine blades • TV reception can be affected by wind farms • The development of wind energy has required significant government subsidies – some people argue that this money could have been better spent elsewhere (opportunity cost) • Many wind farms are sited in coastal locations where land is often very expensive

Public finance continues to play a strong role in the economics of the industry and this is likely to continue in the foreseeable future, particularly in the light of the current global financial situation and the fragility of commercial banks.

Apart from establishing new wind energy sites, repowering is also beginning to play an important role. This means replacing first generation wind turbines with modern multi-megawatt turbines that give a much better performance. The advantages are:

- more wind power from the same area of land
- fewer wind turbines
- higher efficiency, lower costs
- enhanced appearance as modern turbines rotate at a lower speed and are usually more visually pleasing due to enhanced design
- better grid integration as modern turbines use a connection method similar to conventional power plants.

As wind turbines have been erected in more areas of more countries, the opposition to this form of renewable energy has increased:

- People are concerned that huge turbines located nearby could blight their homes and have a significant impact on property values
- Concerns about the hum of turbines disturbing both people and wildlife
- Skylines in scenically beautiful areas might be spoiled forever
- Turbines can kill birds – migratory flocks tend to follow strong winds, but wind companies argue they steer clear of migratory routes
- Suitable areas for wind farms are often near the coast where land is expensive
- Turbines can affect TV reception nearby
- The opportunity cost of heavy investment in wind compared to the alternatives.

The recent rapid increase in demand for turbines has resulted in a shortage of supply. New projects now have to make orders for turbines in large blocks up to several years in advance to ensure firm delivery dates from manufacturers. Likewise, the investment from manufacturers is having to rise significantly to keep pace with such buoyant demand.

New developments in wind energy include:

- in 2008, a Dutch company installed the world's first floating wind turbine off the southern coast of Italy in water 110 metres deep – the technology is known as the Submerged Deepwater Platform System.
- the Swedish company Nordic has recently brought a two-bladed turbine onto the market.

Biofuels

Biofuels are fossil fuel substitutes that can be made from a range of agri-crop materials including oilseeds, wheat, corn and sugar. They can be blended with petrol and diesel.

In recent years, increasing amounts of cropland have been used to produce biofuels. Initially, environmental groups such as Friends of the Earth and Greenpeace were very much in favour of biofuels, but as the damaging environmental consequences became clear, such environmental organisations were the first to demand a rethink of this energy strategy.

The main methods of producing biofuels are:

- crops that are high in sugar (sugar cane, sugar beet, sweet sorghum) or starch (corn/maize) are grown and then yeast fermentation is used to produce ethanol
- plants containing high amounts of vegetable oil (such as oil palm, soybean and jatropha) are grown, and the oils derived from them are heated to reduce their viscosity; they can then be burned directly in a diesel engine, or chemically processed to produce fuels such as biodiesel

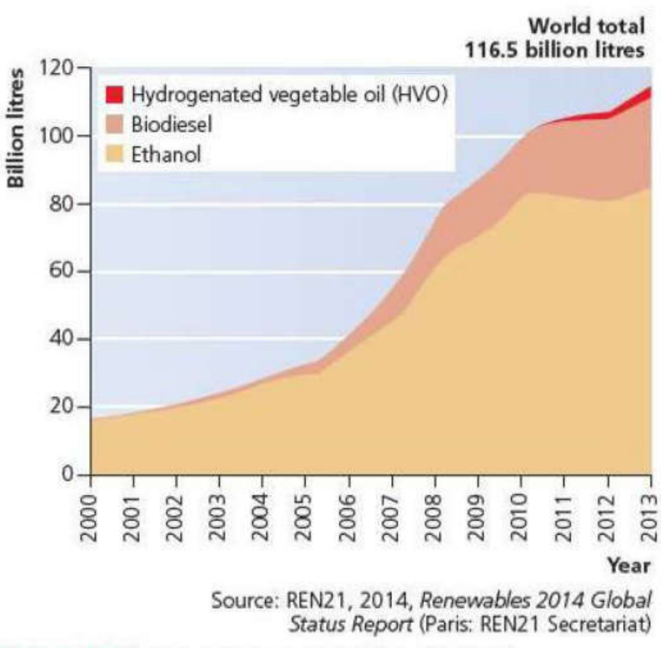
- wood can be converted into biofuels such as woodgas, methanol or ethanol fuel
- cellulosic ethanol can be produced from non-edible plant parts, but costs are not economical at present – this method is seen as the potential second generation of biofuels.

Ethanol is the most common biofuel globally, particularly in the USA and Brazil (Figure 12.15). It accounts for over 90 per cent of total biofuel production. Ethanol can be used in petrol engines when mixed with gasoline. Most existing petrol engines can run on blends of up to 15 per cent ethanol. Global production of ethanol has risen rapidly in recent decades, although since 2010 it has levelled off to a considerable extent. In the USA, about 40 per cent of the maize crop is used to produce ethanol. The USA and Brazil are by far the largest producers of ethanol in the world. Together, these two countries produce 87 per cent of the world total. However, production in the European Union and China is growing significantly.

In contrast to the USA, Brazil uses sugar cane to produce ethanol. More than half of Brazil's sugar cane crop is now used for this purpose. Sugar cane-based ethanol can be produced in Brazil at about half the cost of maize-based ethanol in the USA. This difference is due to:

- climatic factors
- land availability
- the greater efficiency of sugar in converting the Sun's energy into ethanol.

The USA has set a target of increasing the use of biofuels to 15 billion gallons by 2015. Subsidies are an important element in encouraging biofuel production.



Source: REN21, 2014, *Renewables 2014 Global Status Report* (Paris: REN21 Secretariat)

Figure 12.15 Global biofuel production, 2000–13

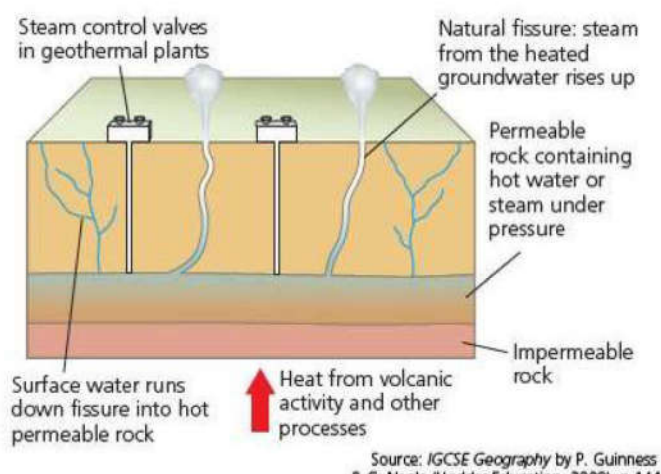
Global biodiesel production and capacity have risen significantly in recent years. Biodiesel is the most common biofuel produced in Europe, with the continent accounting for over 60 per cent of global production. Germany and France are the leading producers within Europe. Biodiesel can be used in any diesel engine when mixed with mineral diesel, usually up to a limit of 15 per cent biodiesel. Rapeseed oil is the major source of Europe's biodiesel. After the EU, the USA is the second most important producer of biodiesel. In the latter, soybean oil is the main source for production.

Increasing investment is taking place in research and development of the so-called 'second generation' biodiesel projects including algae and cellulosic diesel. Other important trends in the industry are a transition to larger plants and consolidation among smaller producers.

Geothermal electricity

Geothermal energy is the natural heat found in the Earth's crust in the form of steam, hot water and hot rock. Rainwater may percolate several kilometres below the surface in permeable rocks, where it is heated due to the Earth's **geothermal gradient**. This is the rate at which temperature rises as depth below the surface increases. The average rise in temperature is about 30 °C per kilometre, but the gradient can reach 80 °C near plate boundaries.

This source of energy can be used to produce electricity, or its hot water can be used directly for industry, agriculture, bathing and cleansing (Figure 12.16). For example, in Iceland hot springs supply water at 86 °C to 95 per cent of the buildings in and around Reykjavik. At present, virtually all the geothermal power plants in the world operate on steam resources, and they have an extremely low environmental impact.



Source: *IGCSE Geography* by P. Guinness & G. Nagle (Hodder Education, 2009), p.144

Figure 12.16 Geothermal power

Figure 12.17 Geothermal power plant, Wairakei, New Zealand

First begun in Larderello, Italy, in 1904, total world installed geothermal capacity passed 12000megawatts by the end of 2013. This is enough electricity to meet the needs of over 70million people. About 700 geothermal projects were under development in 76 countries in 2013, amounting to about 30000megawatt capacity. The USA is the world leader in geothermal electricity, with plants in Alaska, California, Hawaii, Nevada and Utah. Total production accounts for about 0.4per cent of the electricity used in the USA. Other leading geothermal-electricity-using countries are the Philippines, Indonesia, Mexico, Italy, New Zealand (Figure 12.17), Iceland and Japan.

The advantages of geothermal power for those countries that have access to this form of energy are:

- extremely low environmental impact
- plants occupy relatively small land areas
- generation is not dependent on weather conditions (like wind and solar power)
- relatively low maintenance costs.

The limitations of this form of energy are:

- there are few locations worldwide where significant amounts of energy can be generated
- total global generation remains small
- some of the best locations are far from where the energy could be used
- installation costs of plant and piping are relatively high.

Solar power

From a relatively small base, the installed capacity of solar electricity is growing rapidly. Experts say that solar power has huge potential for technological improvement, which could make it a major source of global electricity in years to come (Figure 12.18). In 2000, global solar capacity was only 1275megawatts. It grew to 5085megawatts in 2005 and 40183 in 2010. Global solar power capacity passed the milestone of 100000megawatts in 2012 and was close to 137000 by the end of 2013. This is a rapid rate of increase that is likely to continue. Current solar electricity generation amounts to about 0.5per cent of all global electricity generation. Germany, China, Italy, Japan, USA and Spain currently lead the global market for solar power.

Figure 12.18 Solar electricity generated by photovoltaic panels in Spain

Solar electricity is currently produced in two ways:

- **Photovoltaic (PV) systems** – solar panels that convert sunlight directly into electricity.
- **Concentrating solar power (CSP) systems** – use mirrors or lenses and tracking systems to focus a large area of sunlight into a small beam. This concentrated light is then used as a heat source for a conventional thermal power plant. The most developed CSP systems are the solar trough, parabolic dish and solar power tower. Each method varies in the way it tracks the Sun and focuses light. In each system, a fluid is heated by the concentrated sunlight, and is then used for power generation or energy storage.

Another idea being considered is to build solar towers. Here, a large glassed-in area would be constructed with a very tall tower in the middle. The hot air in this 'greenhouse' would rise rapidly up the tower, driving turbines along the way.

Traditional solar panels comprise arrays of photovoltaic cells made from silicon. These cells absorb photons in light and transfer their energy to electrons, which form an electrical circuit. However, standard solar panels:

- are costly to install
- have to be tilted and carefully positioned so as not to shade neighbouring panels.

A number of companies are now developing a new technique to manufacture solar panels. This involves using different materials and building them in very thin layers or films, almost like printing on paper, to produce the photovoltaic effect. The cost of production is reduced because the layers or films use less material, and they can be deposited on bases such as plastic, glass or metal.

Tidal power

Although currently in its infancy, a study by the Electric Power Research Institute has estimated that as much as 10 per cent of US electricity could eventually be supplied by tidal energy. This potential could be equalled in the UK and surpassed in Canada.

Tidal power plants act like underwater windmills, transforming sea currents into electrical current. Tidal power is more predictable than solar or wind power, and the infrastructure is less obtrusive, but start-up costs are high. The 240 megawatt Rance facility in north-western France is the only utility-scale tidal power system in the world. However, the greatest potential is Canada's Bay of Fundy in Nova Scotia. A pilot plant was opened at Annapolis Royal in 1984, which at peak output can generate 20 megawatts. More ambitious projects at other sites along the Bay of Fundy are under consideration, but there are environmental concerns. The main concerns are potential effects on fish populations, levels of sedimentation building up behind facilities and the possible impact on tides along the coast.

Section 12.1 Activities

1 Suggest reasons for the variations and trends in the consumption of hydro-electricity by world region.
2 Discuss recent changes in the installed capacity of wind energy.
3 a What are biofuels?
  b Why has biofuel production expanded so rapidly?
  c Examine the advantages and disadvantages of biofuels.
4 a What is geothermal energy?
  b Explain the geographical locations of the main producing countries.
5 Explain the difference between photovoltaic and concentrated solar power systems.

Fuelwood in LICs

In LICs, about 2.5 billion people rely on fuelwood, charcoal and animal dung for cooking (Figure 12.19). Fuelwood and charcoal are collectively called fuelwood, which accounts for just over half of global wood production. Fuelwood provides much of the energy needs for Sub-Saharan Africa. It is also the most important use of wood in Asia.

Figure 12.19 Animal dung being dried for fuel in India

According to the World Energy Outlook, 1.3 billion people were still living without access to electricity in 2012. This is equal to 18 per cent of the world's population. Nearly 97 per cent of those without access to electricity live in Sub-Saharan Africa or in Asia. The largest populations without electricity are in India, Nigeria, Ethiopia, Bangladesh, Democratic Republic of Congo and Indonesia.

In LICs, the concept of the **energy ladder** is important. Here, a transition from fuelwood and animal dung to 'higher-level' sources of energy occurs as part of the process of economic development. Income, regional electrification and household size are the main factors affecting the demand for fuelwood. Forest depletion is therefore initially heavy near urban areas but slows down as cities become wealthier and change to other forms of energy. It is the more isolated rural areas that are most likely to lack connection to an electricity grid. It is in such areas that the reliance on fuelwood is greatest. Wood is likely to remain the main source of fuel for the global poor in the foreseeable future.

The collection of fuelwood does not cause deforestation on the same scale as the clearance of land for agriculture, but it can seriously deplete wooded areas. The use of fuelwood is the main cause of indoor air pollution in LICs. Indoor air pollution is responsible for 1.5 million deaths every year. More than half of these deaths are of children below the age of 5.

☐ Trends in high-, middle- and low-income countries

Deindustrialisation, increasing energy efficiency and relatively low population growth in HICs in general has resulted in a decrease in primary energy consumption in all four HICS considered in Table 12.8. The decrease in the USA is marginal, but more significant in Japan, Germany

Table 12.8 Primary energy consumption, 2002–12 (million tonnes oil equivalent)

	Country	2002	2012
HICs	USA	2295.5	2208.8
	Japan	513.3	478.2
	Germany	334.0	311.7
	UK	221.7	203.6
MICs	South Korea	203.0	271.1
	Malaysia	53.1	76.3
	China	1073.8	2735.2
	India	310.8	563.5
LICs	Bangladesh	14.8	26.3
	Pakistan	47.4	69.3
	Peru	12.1	22.3
	Algeria	28.6	44.6

and the UK. There are examples of HICs, such as Canada and Spain, where energy consumption increased during this ten-year time period, but such increases have been modest. In such countries, there is every prospect that they will follow the example of the four HICS considered in Table 12.8 in due course.

In contrast in the MICs, growth rates were considerable and consistent with high rates of economic growth. Consumption in China increased at an incredible rate. In 2002, energy consumption in China was less than half that of the USA. By 2012, it was almost 24 per cent higher! India, which consumed less primary energy than Japan and Germany in 2002, now consumes considerably more than both of these countries. In the same time period, South Korea overtook the UK in primary energy consumption.

Although most LICs struggle to fund their energy requirements, all four countries in Table 12.8 show a significant increase in primary energy consumption. Energy is vital for economic growth and to satisfy the basic demands of growing populations. Bangladesh, which has a considerably higher population than both South Korea and Malaysia, consumed far less energy than both of its Asian neighbours in 2012, even though its own energy consumption rose significantly in the period under consideration.

There is a strong positive correlation between GNP per person and energy use. In poor countries, it is the high- and middle-income groups who generally have enough money to purchase sufficient energy, and they also tend to live in locations where electricity is available. It is the poor in such countries who lack access to the advantages that electricity brings.

The environmental impact of energy

Increasing energy insecurity has stimulated exploration of technically difficult and environmentally sensitive areas. Such exploration and development is economically feasible when energy prices are high, but becomes less so when prices fall. No energy production location has suffered more environmental damage than the Niger delta in West Africa.

Case Study: The Niger delta

The Niger delta (Figure 12.20) covers an area of 70 000 km², making up 7.5 per cent of Nigeria's land area. It contains over 75 per cent of Africa's remaining **mangroves**. A report published in 2006 estimated that up to 1.5 million tonnes of oil has been spilt in the delta over the last 50 years. The report, compiled by WWF, says that the delta is one of the five most polluted spots on Earth. Pollution is destroying the livelihoods of many of the 20 million people who live in the delta. The pollution damages crops and fishing grounds, and is a major contributor to the upsurge in violence in the region. People in the region are dissatisfied with bearing the considerable costs of the oil industry but seeing very little in terms of the benefits. The report accused the oil companies of not using the advanced technologies available to them to combat pollution. However, Shell claims that 95 per cent of oil discharges in the last five years have been caused by sabotage.

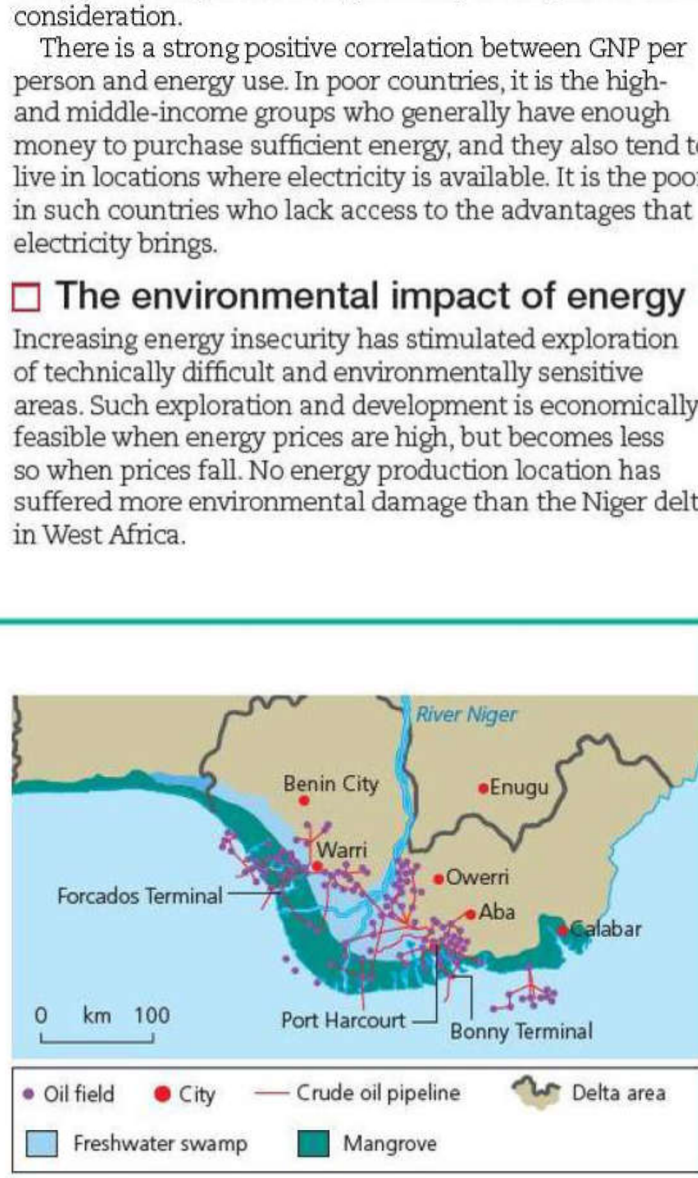


Figure 12.20 Map of oil fields in the Niger Delta

The flaring (burning) of unwanted natural gas found with the oil is a major regional and global environmental problem. The gas found here is not useful because there is no gas pipeline infrastructure to take it to consumer markets. It is estimated that 70 million m^3 are flared off each day. This is equivalent to 40 per cent of Africa's natural gas consumption. Gas flaring in the Niger delta is the world's single largest source of greenhouse gas emissions.

One of the world's largest wetlands, and Africa's largest remaining mangrove forest, has suffered an environmental disaster:

- Oil spills, acid rain from gas flares and the stripping away of mangroves for pipeline routes have killed off fish.
- Between 1986 and 2003, more than 20 000 hectares of mangroves disappeared from the coast, mainly due to land clearing and canal dredging for oil and gas exploration.
- The oilfields contain large amounts of natural gas. This is generally burnt off as flares rather than being stored or reinjected into the ground. Hundreds of flares have burned continuously for decades. This causes acid rain and releases greenhouse gases.
- The government has recognised 6817 oil spills in the region since the beginning of oil production. Critics say the number is much higher.
- Construction and increased shipping have changed local wave patterns, causing shore erosion and the migration of fish into deeper water.
- Various types of construction have taken place without adequate environmental impact studies.

The federal environmental protection agency has only existed since 1988 and **environmental impact assessments** were not compulsory until 1992.

In early 2015, the major oil company Royal Dutch Shell agreed to an $84 million settlement with the Bodo community in the Niger delta for two oil spills that were among the biggest spills in decades in Nigeria. Thousands of hectares of mangrove were affected. The money will go to over 15 000 fishermen whose livelihoods were affected and to the community in general. According to Amnesty International, Royal Dutch Shell and the Italian company ENI have admitted to more than 550 oil spills in the Niger delta in 2014. By contrast, on average, there were only 10 spills a year across the whole of Europe between 1971 and 2011.

Case Study: Oil sands in Canada and Venezuela

Huge **oil-sand deposits** in Alberta, Canada, and Venezuela could be critical over the next 50 years as the world's production of conventional oil falls. The oil sands are a mixture of bitumen and sand. The bitumen will not flow unless heated or diluted with lighter hydrocarbons to make it transportable by pipelines and usable by refineries. Such synthetic oil, which can also be made from coal and natural gas, could provide a vital bridge to an era of new technologies. The government of Alberta estimates that recoverable oil reserves total about 200 billion barrels.

In 2012, the oil sands provided direct employment to over 22 000 workers, but indirect employment is many times higher. Current production is about 1.3 million barrels a day. This is expected to grow to 3 million barrels a day by 2020. In 2012, 56 per cent of Canada's total oil production came from oil sands. Alberta's oil sands are the third largest oil reserve in the world (Figure 12.21).

However, there are serious environmental concerns about the development of oil sands, which have a big carbon footprint:

- It takes 2 tonnes of mined sand to produce 1 barrel of synthetic crude, leaving lots of waste sand.
- It takes about three times as much energy to produce a barrel of Alberta oil-sands crude as it does a conventional barrel of oil. Thus, oil sands are large sources of greenhouse gas emissions.
- Oil sands require 2–4.5 barrels of water to produce a single barrel of oil.
- The development of oil sands has had a huge impact on the landscape, including the removal of a significant area of boreal forest.

The environmental organisation Greenpeace has called on the Canadian government and the oil companies to stop the development of oil sands on environmental, health and social grounds.

Venezuela's heavy oil production has not kept pace with that of Canada, but in 2013 it totalled over 1.25 million barrels a day.

Figure 12.21 Operations in Alberta's oil sands

Pathways crossing difficult environments

Energy pathways are supply routes between energy producers and consumers that may be pipelines, shipping routes or electricity cables. As energy companies have had to search further afield for new sources of oil, new energy pathways have had to be constructed. Some major oil and gas pipelines cross some of the world's most inhospitable terrain. The Trans-Alaskan Pipeline (TAP) crosses three mountain ranges and several large rivers. Much of the pipeline is above ground to avoid the permafrost problem. Here, the ground is permanently frozen down to about 300 metres, apart from the top metre, which melts during the summer. Building foundations and the uprights that hold the pipeline above ground have to extend well below the melting zone (called the 'active layer'). The oil takes about 6 days to make the 1270 kilometre journey. Engineers fly over the pipeline every day by helicopter to check for leaks and other problems. Problems such as subsidence have closed the pipeline for short periods.

Section 12.1 Activities

1 Why is fuelwood a vital source of energy in many poor countries?
2 With reference to Table 12.8, describe and explain contrasting trends in energy consumption between HICs, MICs and LICs.
3 The Niger delta has been described as an 'environmental disaster area'. Briefly discuss this assertion.
4 Outline the advantages and disadvantages of exploiting oil-sand deposits.
5 What are energy pathways and why are they so important?

12.2 The management of energy supply

Case Study: China

China's energy mix

China is the biggest consumer and producer of energy in the world (Table 12.9). It overtook the USA in total energy usage in 2009. The USA had held the top position in the energy usage league for more than a century. In 2012, China consumed 2.74 billion tonnes of oil equivalent, compared with 2.2 billion tonnes in the USA. The demand for energy in China continues to increase significantly as the country expands its industrial base. However, energy usage per person in the USA is much higher, with the average American using more than four times the Chinese average.

China's energy consumption rose by 45 per cent in the 7 years to 2013, according to data from the National Bureau of Statistics. However, in 2014 the Chinese government announced plans to cap the increasing rate at which it consumes energy to 28 per cent for the seven-year period to 2020.

Table 12.9 China's Key Energy Statistics

		World rank
Total primary energy production 2012	101.781 quadrillion British thermal units	1
Total primary energy consumption 2012	105.882 quadrillion British thermal units	1
Total primary coal production 2012	4 017 920 thousand short tons	1
Total petroleum consumption 2013	10 480 thousand barrels per day	2
Total electricity net generation 2012	4 768 billion kilowatt hours	1

Source: eia.gov/beta/international/country

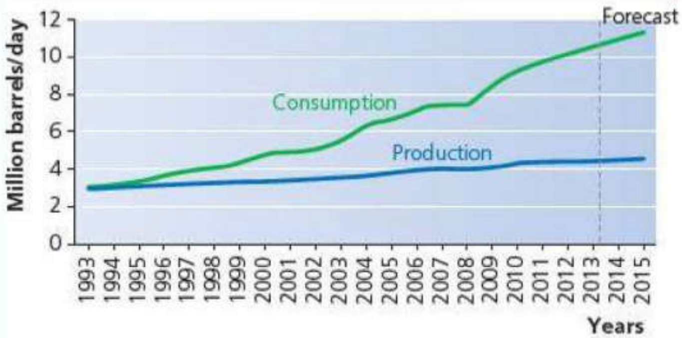
In 2012, China's energy consumption breakdown by energy source was:

- **coal**: 68.4 per cent
- **oil**: 17.6 per cent
- **hydro-electricity**: 7.1 per cent
- **natural gas**: 4.7 per cent
- **nuclear energy**: 0.8 per cent
- **renewable energy** (other than hydro-electricity): 1.2 per cent.

An evolving energy policy

China's energy policy has evolved over time. As the economy expanded rapidly in the 1980s and 1990s, much emphasis was placed on China's main energy resource, coal, in terms of both increasing production and building more coal-fired power stations. However, this was at the expense of huge environmental impact and an alarmingly high casualty rate among coal miners. In 2012, China consumed just over half of the world's coal. Between 2003 and 2013, China accounted for 87 per cent of the growth in global coal consumption. Coal is the dirtiest of the fossil fuels and thus the environmental consequences of such a heavy reliance on coal were all too predictable. According to Greenpeace, 80 per cent of China's carbon dioxide emissions and 85 per cent of its sulphur dioxide pollution comes from burning coal. China is the world's leading energy-related CO_2 emitter. In November 2014, China unveiled an accord aimed at limiting carbon emissions.

China was also an exporter of oil until the early 1990s, although it is now a very significant importer (Figure 12.22). China is the world's second largest consumer of oil, and moved from second largest net importer of oil to the largest in 2014. This transformation has had a major impact on Chinese energy policy as the country has sought to secure overseas



Source: EIA International Energy Statistics and Short-Term Energy Outlook, January 2014

Figure 12.22 Chinese oil consumption and production, 1993–2015

sources of supply. As a result, China has had an increasing influence on the global energy market. Long-term energy security is viewed as essential if the country is to maintain the pace of its industrial revolution.

In recent years, China has tried to take a more balanced approach to energy supply and at the same time reduce its environmental impact. The 11th Five-Year Plan (2006–10) focused on two major energy-related objectives: **a** to reduce energy use per unit GDP by 20 per cent and **b** to ensure a more secure supply of energy. Because of the dominant position of coal in China's energy mix, the development of clean coal technology is central to China's energy policy with regard to fossil fuels. China has emerged in the last two years as the world's leading builder of more efficient, less polluting coal power plants. China has begun constructing such clean coal plants at a rate of one a month. The government has begun to require that power companies retire an older, more polluting power plant for each new one they build.

The further development of nuclear and hydropower is another important strand of Chinese policy. The country also aims to stabilise and increase the production of oil while augmenting that of natural gas and improving the national oil and gas network. Nuclear power reached a capacity of 9.1 gigawatts by the end of 2008, with a target capacity of 40 gigawatts by 2020. By the end of 2009, China had 11 operational nuclear reactors with a further 17 under construction. The World Nuclear Association (WNA) says that China has a further 124 nuclear reactors on the drawing board. This will lead to a dramatic increase in China's demand for uranium, the raw material of nuclear reactors.

China's strategic petroleum reserve

As part of China's concerns about energy security and its increasing reliance on oil imports, the country is developing a strategic petroleum reserve (Figure 12.23). The plan is for China to build facilities that can hold 500 million barrels of crude oil by 2020 in three phases. This will be equivalent to about 90 days' supply. Phase 1, completed in 2009, consists of four sites with a total storage capacity of 103 million barrels. Phase 2, to be completed by the end of 2015, will add a further 170 million barrels of storage capacity.

Figure 12.23 China's strategic petroleum reserve (SPR)

China is following the USA and other countries in building up a petroleum reserve. This will protect China to a certain extent from fluctuations in the global oil price, which can arise for a variety of reasons.

Renewable energy policy

China aims to produce at least 15 per cent of overall energy output from renewable energy sources by 2020 as the government seeks to improve environmental conditions. Renewable energy currently contributes more than one-quarter of China's total installed energy capacity, with hydro-electricity by far the largest contributor. China produces more hydro-electricity than any other country in the world, with hydro-electricity accounting for more than 15 per cent of the country's total electricity generation. The world's largest hydro-electricity project, the Three Gorges Dam along the Yangtze River, was completed in 2012. It has 32 generators with a total maximum capacity of 22.5 gigawatts.

China is now the world leader in wind energy, currently accounting for 31 per cent of global installed wind-power capacity. The year 2008 saw the initial development of China's offshore wind farm policy. China's wind turbine manufacturing industry is now the largest in the world. Chinese policy is not just to gain the energy advantages of wind energy but also to develop it as a significant industrial sector. China is now also the largest manufacturer of solar PV. The solar hot-water market in China has also continued to boom, partly as a result of a new rural energy subsidy programme for home appliances, for which solar hot water qualifies. China aims to increase solar electricity capacity from 3 gigawatts in 2012 to 35 gigawatts by the end of 2015.

The Three Gorges Dam

The Three Gorges Dam across the Yangtze River in China is the world's largest electricity-generating plant of any kind (Figures 12.24 and 12.25). The dam is over 2 kilometres long and 100 metres high. The lake impounded behind it is over 600 kilometres long. All of the originally planned components

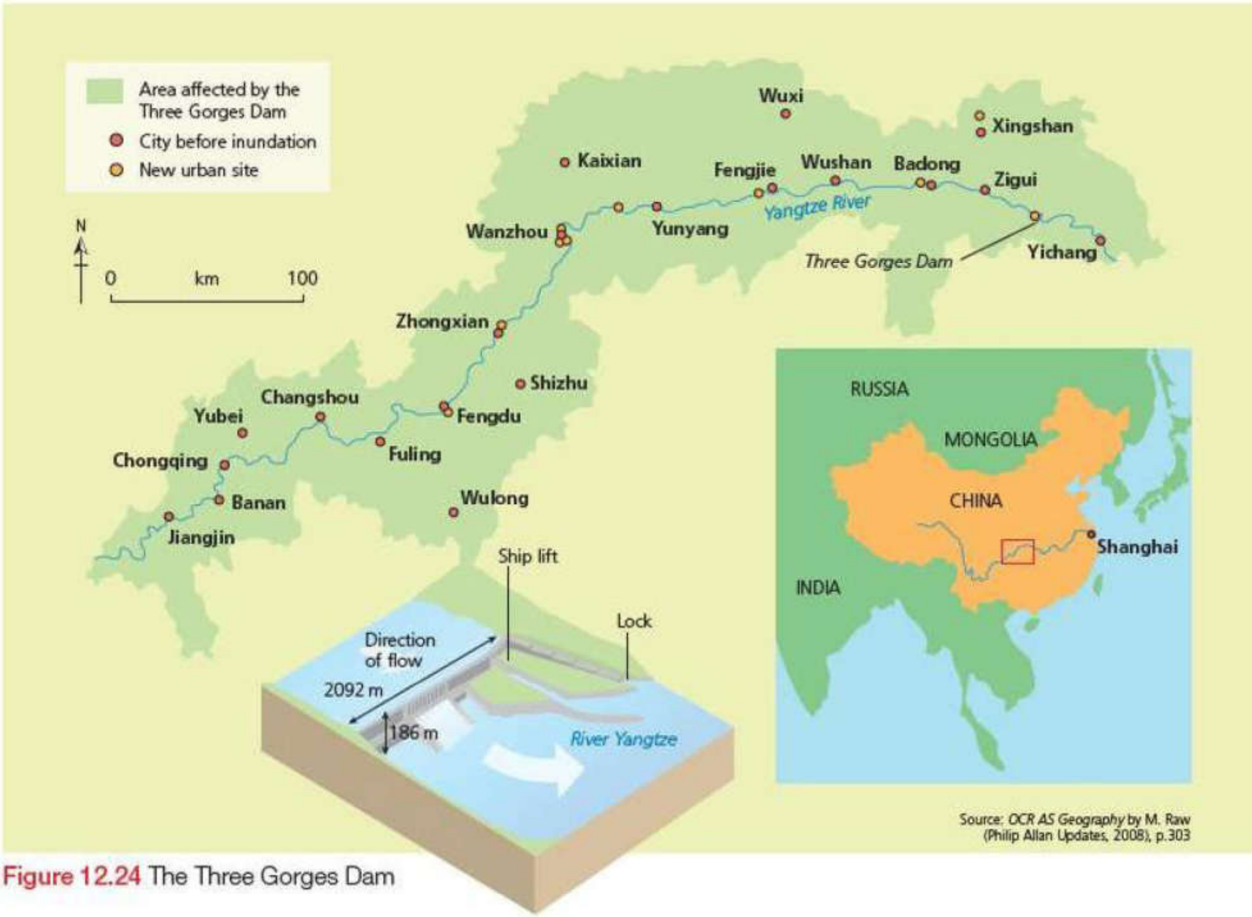


Figure 12.24 The Three Gorges Dam

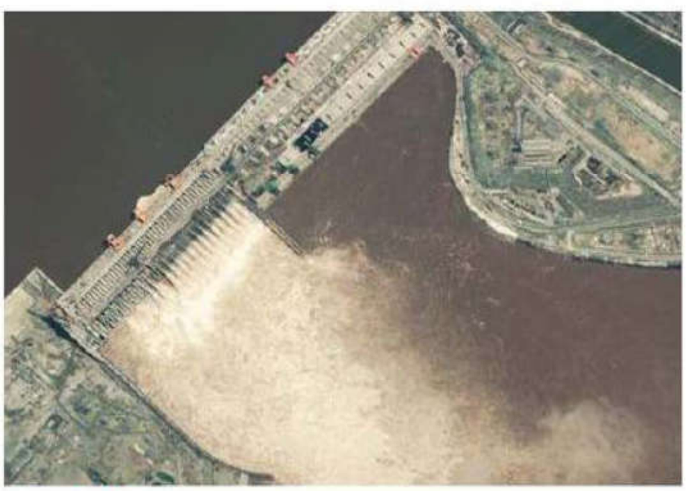


Figure 12.25 The Three Gorges Dam

were completed in late 2008. The Dam began running at full capacity in mid-2012 when the last of its 32 generators became operational. Total generating capacity is now 22.5 gigawatts.

One objective of such a large capacity is to reduce China's dependence on coal. The dam supplies Shanghai and Chongqing in particular with electricity. This is a multipurpose scheme that also increases the river's navigation capacity and reduces the potential for floods downstream. The dam has raised water levels by 90 metres upstream, transforming the rapids in the gorge into a lake, allowing shipping to function in this stretch of the river. The dam protects an estimated 10 million people from flooding.

However, there was considerable opposition to the dam because:

- over 1 million people had to be moved to make way for the dam and the lake
- much of the resettlement has been on land above 800 metres above sea level, which is colder and has less fertile soils
- the area is seismically active and landslides are frequent
- there are concerns that silting will quickly reduce the efficiency of the project
- significant archaeological treasures were drowned
- the dam interferes with aquatic life
- the total cost is estimated at $70 billion; many people argue that this money could have been better spent.

Section 12.2 Activities

1 Describe China's energy mix.
2 Comment on the trends in China's production and consumption of oil shown in Figure 12.22.
3 Why is China developing a strategic petroleum reserve?
4 Discuss China's renewable energy policy.
5 a Explain the objectives of the Three Gorges Dam.
  b For what reasons was the construction of the Three Gorges Dam opposed?

12.3 Environmental degradation

☐ Pollution: land, air and water

Pollution is the dominant factor in the environmental degradation of land, air and water and impacts significantly on human health. Figure 12.26 shows the considerable global variations in deaths from urban air pollution. Compare the relatively low incidence in southern and eastern Africa and western Europe with the very high level in China and a number of other Asian countries (Figure 12.27). A recent report by the World Health Organization estimates that about 8 million people died in 2012 as a result of air pollution. This figure comprised:

Figure 12.27 Air pollution over Ulaanbaatar, Mongolia

- **3.7 million deaths attributable to ambient air pollution** – 88 per cent of those premature deaths occurred in LICs and MICs
- **4.3 million deaths attributable to household air pollution** – almost all of these deaths occurred in LICs and MICs. About 3 billion people cook and heat their homes using solid fuels (that is, wood, crop wastes, charcoal, coal and dung) in open fires and leaky stoves.

These findings are higher than previous estimates and confirm that air pollution is the world's greatest single environmental health risk.

A study in China revealed that children exposed to highly polluted air while in the womb had more changes in their DNA, and a higher risk of developmental problems, than those whose mothers breathed cleaner air during pregnancy. Apart from the direct effects on health of pollution there are considerable indirect economic effects, which include:

- the cost of healthcare for pollution-related illnesses
- interruptions to the education of children, which may cause them to leave school with lower qualifications than expected
- lost labour productivity.

Pollution has a considerable negative impact on ecosystems all over the world. In some regions, the changes brought about by pollution have been little short of catastrophic.

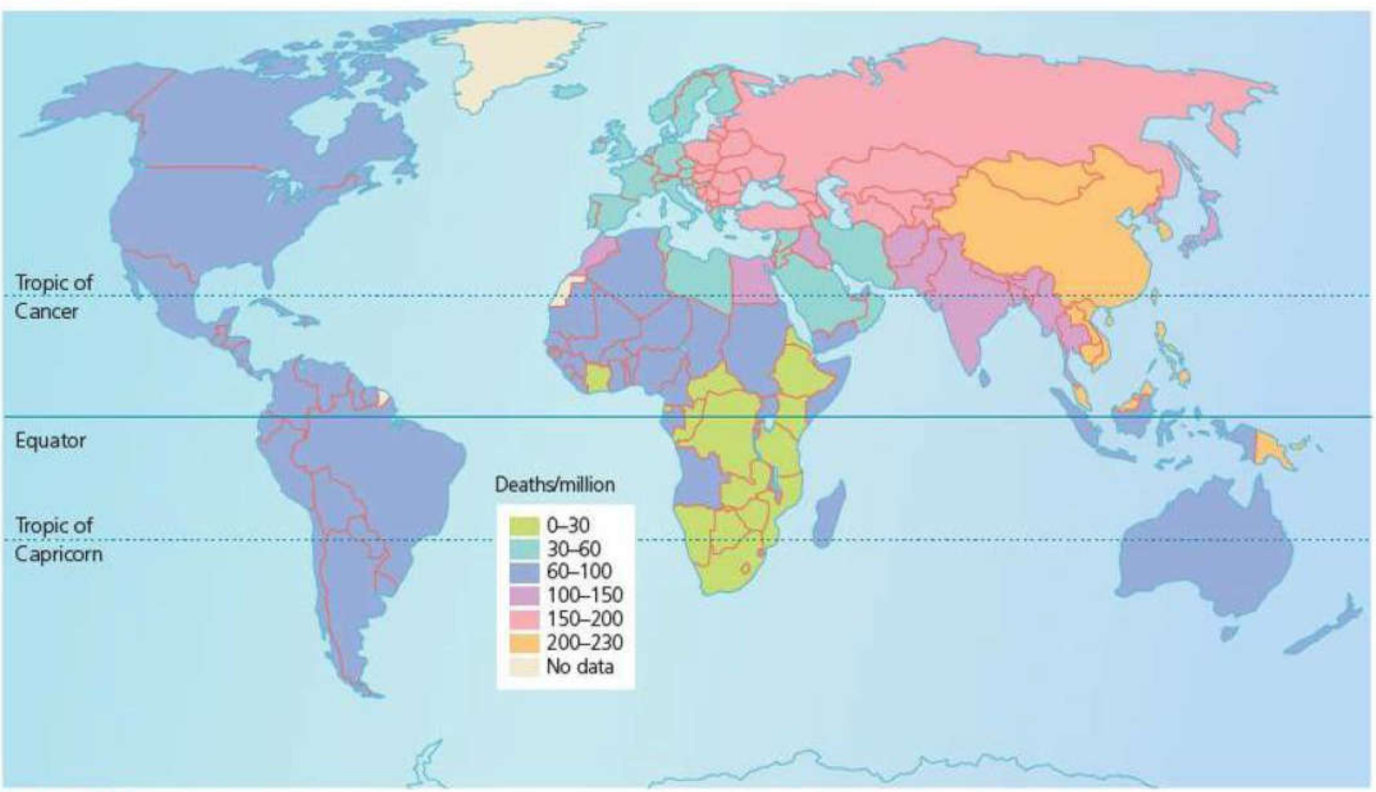


Figure 12.26 Global distribution of deaths from urban air pollution

Case Study: Environmental degradation in the Niger delta

The Niger delta covers an area of 70 000 km², making up 7.5 per cent of Nigeria's land area. It contains over 75 per cent of Africa's remaining mangrove. A report published in 2006 estimated that up to 1.5 million tonnes of oil has been spilt in the delta over the last 50 years. The report, compiled by WWF, says that the delta is one of the five most polluted spots on Earth. Pollution is destroying the livelihoods of many of the 20 million people who live there. The pollution damages crops and fishing grounds and is a major contributor to the upsurge in violence in the region. People in the region are dissatisfied with bearing the considerable costs of the oil industry but seeing very little in terms of the benefits. The report accused the oil companies of not using the advanced technologies to combat pollution that are evident in other world regions. However, shell claims that 95 per cent of oil discharges in the last five years have been caused by sabotage.

The flaring (burning) of unwanted natural gas found with the oil is a major regional and global environmental problem. The gas found here is not useful because there is no gas pipeline infrastructure to take it to consumer markets. It is estimated that 70 million m³ are flared off each day. This is equivalent to 40 per cent of Africa's natural gas consumption. Gas flaring in the Niger delta is the world's single largest source of greenhouse-gas emissions.

Figure 12.28 Environmental problems in the Niger delta

Virtually every substance is toxic at a certain dosage. The most serious polluters are the large-scale processing industries, which tend to form agglomerations as they have similar locational requirements (Table 12.10). The impact of a large industrial agglomeration may spread well beyond the locality and region, to cross international borders. For example, prevailing winds in Europe generally carry pollution from west to east. Thus the problems caused by acid rain in Scandinavia have been due partly to industrial activity in the UK. Dry and wet deposition can be carried for considerable distances. For example, pollution found in Alaska in the 1970s was traced back to the Ruhr industrial area in Germany.

Table 12.10 The most polluting industries

Industrial sector	Examples
Fuel and power	Power stations, oil refineries
Mineral industries	Cement, glass, ceramics
Waste disposal	Incineration, chemical recovery
Chemicals	Pesticides, pharmaceuticals, organic and inorganic compounds
Metal industries	Iron and steel, smelting, non-ferrous metals
Others	Paper manufacture, timber preparation, uranium processing

Pollution is the major externality of industrial and urban areas. It is at its most intense at the focus of pollution-causing activities, declining with distance from such concentrations. For some sources of pollution, it is possible to map the externality gradient and field (Figure 12.29). In general, health risk and environmental impact is greatest immediately around the source of pollution, and the risk decreases with distance from the source. However, atmospheric conditions and other factors can complicate this pattern. Exposure to pollution can result in health and environmental effects (Table 12.11) that range from fairly minor to severe.

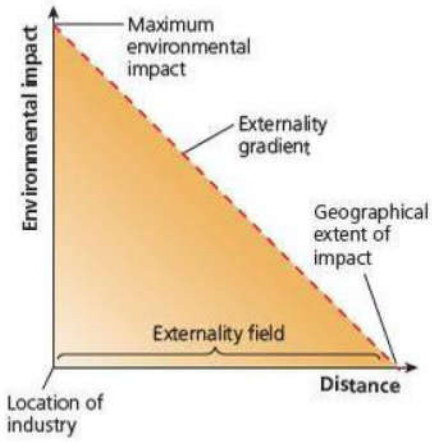


Figure 12.29 Externality gradient and field

Table 12.11 Major sources and health and environmental effects of air pollutants

	Major sources	Health effects	Environmental effects
Sulphur dioxide (SO_2)	Industry	Respiratory and cardiovascular illnesses	Precursor to acid rain, which damages lakes, rivers and trees; damage to cultural relics
Nitrous oxide (NO_x)	Vehicles, industry	Respiratory and cardiovascular illnesses	Nitrogen deposition leading to overfertilisation and eutrophication
Particulate matter	Vehicles, industry	Particles penetrate deep into lungs and can enter bloodstream	Visibility
Carbon monoxide (CO)	Vehicles	Headaches and fatigue, especially in people with weak cardiovascular health	
Lead (Pb)	Vehicles (burning leaded gasoline)	Accumulates in bloodstream over time; damages nervous system	Kills fish/animals
Ozone (O_3)	Formed from reaction of nitrous oxides and VOCs	Respiratory illnesses	Reduced crop production and forest growth; smog precursor
Volatile organic compounds (VOCs)	Vehicles, industrial processes	Eye and skin irritation; nausea, headaches; carcinogenic	Smog precursor

Strategies to tackle air pollution

Considering the intense use of energy and materials, levels of pollution have generally declined in HICs:

- In recent decades, increasingly strict environmental legislation has been passed in these countries. This is the beginning of a process to make polluters pay for the cost of their actions themselves, rather than expecting society as a whole to pay the costs.
- Industry has spent increasing amounts on research and development to reduce pollution – the so-called 'greening of industry'.
- The most polluting activities, such as commodity processing and heavy manufacturing, have been relocated to the emerging market economies.
- The expectation is that after a certain stage of economic development in a country, the level of pollution and the degradation it causes will decline (Figure 12.30).

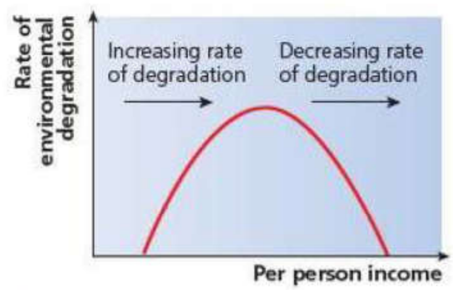


Figure 12.30 The environmental Kuznets curve

Types and amounts of pollution change with economic development. In low-income economies where primary industries frequently dominate, pollution related to agriculture and mining often predominates. As countries industrialise, manufacturing industries, energy production and transport become major polluters. The focal points of pollution will be the large urban-industrial complexes. The NICs of the world are in this stage. In contrast, the HICs have experienced deindustrialisation as many of their major polluting industries have filtered down to NICs. This has resulted in improved environmental conditions in many HICs in general, although pollution from transportation has often increased.

Figure 12.31 shows the measures advocated by the World Health Organization to reduce pollution and its multitude of adverse effects.

It is important to consider the different levels of impact between one-off pollution incidents (**incidental pollution**) and longer-term pollution (**sustained pollution**). The former is mainly linked to major accidents caused by technological failures and human error. Consequences of the latter include ozone depletion and global warming. Some of the worst examples of incidental pollution are shown in Table 12.12.

Major examples of incidental pollution, such as Chernobyl and Bhopal, can have extremely long-lasting consequences that are often difficult to determine in the earlier stages. The effects of both accidents are still being felt more than two decades after they occurred.

There are many examples of successful policies in transport, urban planning, power generation and industry that reduce air pollution:

- **For industry** – clean technologies that reduce industrial smokestack emissions; improved management of urban and agricultural waste, including capture of methane gas emitted from waste sites as an alternative to incineration (for use as biogas)
- **For transport** – shifting to clean modes of power generation; prioritising rapid urban transit, walking and cycling networks in cities as well as rail interurban freight and passenger travel; shifting to cleaner heavy-duty diesel vehicles and low-emissions vehicles and fuels, including fuels with reduced sulfur content
- **For urban planning** – improving the energy efficiency of buildings and making cities more compact, and thus energy efficient
- **For power generation** – increased use of low-emissions fuels and renewable combustion-free power sources (like solar, wind or hydropower); co-generation of heat and power; and distributed energy generation (for example mini-grids and rooftop solar-power generation)
- **For municipal and agricultural waste management** – strategies for waste reduction, waste separation, recycling and reuse or waste reprocessing, as well as improved methods of biological waste management such as anaerobic waste digestion to produce biogas, are feasible, low-cost alternatives to the open incineration of solid waste; where incineration is unavoidable, then combustion technologies with strict emission controls are critical.

Figure 12.31 The World Health Organization – reducing air pollution

It is usually the poorest people in a society who are exposed to the risks from both incidental and sustained pollution. In the USA, the geographic distribution of both minorities and the poor has been found to be highly correlated to the distribution of air pollution, municipal landfills and incinerators, abandoned toxic waste dumps and lead poisoning in children. The race correlation is even stronger than the class correlation. Unequal environmental protection undermines three basic types of equity:

- **procedural equity**, which refers to the extent that planning procedures, rules and regulations are applied in a non-discriminatory way
- **geographic equity**, which refers to the proximity of communities to environmental hazards and locally unwanted land uses such as smelters, refineries, sewage treatment plants and incinerators

Table 12.12 Major examples of incidental pollution

Location	Causes and consequences
Seveso, Italy	In July 1976, a reactor at a chemical factory near Seveso in northern Italy exploded, sending a toxic cloud into the atmosphere. An area of land 18 km² was contaminated with the dioxin TCDD. The immediate after-effects, seen in a small number of people with skin inflammation, were relatively mild. However, the long-term impact has been much worse. The population is suffering increased numbers of premature deaths from cancer, cardiovascular disease and diabetes.
Bhopal, India	A chemical factory owned by Union Carbide leaked deadly methyl isocyanate gas during the night of 3 December 1984. The plant was operated by a separate Indian subsidiary that worked to much lower safety standards than those required in the USA. It has been estimated that 8000 people died within two weeks, and a further 8000 have since died from gas-related diseases. The NGO Greenpeace puts the total fatality figure at over 20000. Bhopal is recognised as the world's worst industrial disaster.
Chernobyl, Ukraine	The world's worst nuclear power-plant accident occurred at Chernobyl, Ukraine, in April 1986. Reactor number four exploded, sending a plume of highly radioactive fallout into the atmosphere, which drifted over extensive parts of Europe and eastern North America. Two people died in the initial explosion and over 336000 people were evacuated and resettled. In total, 56 direct deaths and an estimated 4000 extra cancer deaths have been attributed to Chernobyl. The estimated cost of $200 billion makes Chernobyl the most expensive disaster in modern history.
Harbin, China	An explosion at a large petrochemical plant in the north-east Chinese city of Harbin released toxic pollutants into a major river. Benzene levels were 108 times above national safety levels. Benzene is a highly poisonous toxin that is also carcinogenic. Water supplies to the city were suspended. Five people were killed in the blast and more than 60 injured; 10000 residents were temporarily evacuated.

- **social equity**, which refers to the role of race and class in environmental decision-making.

Ironically, some government actions have created and exacerbated environmental inequity. More stringent environmental regulations have driven noxious facilities to follow the path of least resistance towards poor, overburdened communities where protesters lack the financial support and professional skills of more affluent areas, or where the prospect of bringing in much-needed jobs justifies the risks in the eyes of some residents.

Sustained pollution: ozone depletion and skin cancer

The ozone layer in the stratosphere prevents most harmful ultraviolet (UV) radiation from passing through the atmosphere. However, chlorofluorocarbons (CFCs) and other ozone-depleting substances have caused an estimated decline of about 4 per cent a decade in the ozone layer of the stratosphere since the late 1970s. Depletion of the ozone layer allows more UV radiation to reach the ground, leading to more cases of skin cancer, cataracts and other health and environmental problems. Widespread global concern resulted in the Montreal Protocol banning the production of CFCs and related ozone-depleting chemicals.

Skin cancer is the fastest-growing type of cancer in the USA. In the UK, it is the second most common cancer in young people aged 20–39. Overexposure to UV radiation is the major cause. Skin cancer generally has a 20- to 30-year latency period. There is a significant relationship between skin cancer and latitude in the USA and Canada. However, the use of tanning salons has also been criticised, with a number of studies linking the use of artificial tanning to cases of skin cancer. The World Health Organization's estimates on UV-related mortality and morbidity are that annually about 1.5 million DALYs (disability-adjusted life years) are lost through excessive UV exposure.

Sustained pollution, such as that caused by ozone-depleting substances, usually takes much longer to have a substantial impact on human populations than incidental pollution, but it is likely to affect many more people in the long term. Likewise, tackling the causes of sustained pollution will invariably be a much more difficult task, as the sources of incidental pollution are much more localised compared with the more ubiquitous nature of sustained pollution.

Case Study: China's 'cancer villages'

China's rapid economic growth has led to widespread environmental problems. Pollution problems are so severe in some areas that the term 'cancer village' has become commonplace. In the village of Xiditou, south-east of Beijing, the cancer rate is 30 times the national average. This has been blamed on water and air contaminated by chemical factories. Tests on tap water have found traces of highly carcinogenic benzene that were 50 per cent above national safe limits. In the rush for economic growth, local governments eagerly built factories, but they had very limited experience of environmental controls. Some facts support this:

- The Chinese government admits that 300 million people drink polluted water.
- This water comes from polluted rivers and groundwater.
- 30 000 children in China die of diarrhoea or other water-borne illnesses each year.
- The River Liao is the most polluted, followed by waterways around Tianjin and the River Huai.

In 2013, the Chinese government promised to tackle 'cancer villages', after a huge social media backlash from both ordinary Chinese people and global campaigners. This related mainly to Huangjiawa, a village in Shandong province, after it emerged that the area has one of the highest rates of stomach cancer in the world. It is thought the wells in the village have been contaminated with toxins from a nearby aluminium smelter, which also pumps pollution into the sky. News of this incident spread rapidly across Weibo, a Chinese social media site similar to Twitter. Greenpeace East Asia estimate that 320 million people are without access to clean drinking water in China and 190 million people are drinking water severely contaminated with hazardous chemicals.

Case Study: The BP oil spill in the Gulf of Mexico

On 20 April 2010, a large explosion occurred on the BP-licensed drilling rig Deepwater Horizon sited in the Gulf of Mexico (Figure 12.32). Eleven oil workers died and a blowout preventer, intended to prevent the release of crude oil, failed to activate. The rig sank in 1500 metres of water, with reports of an oil slick 8 kilometres long on the surface. Oil leaked from the well at sea-floor level for 87 days until 15 July when BP sealed it with a capping stack.

Figure 12.32 Deepwater Horizon exploding

Estimates of the amount of oil gushing from the well reached up to 40 000 barrels a day. The US government estimated that 4.9 million barrels of oil were spilled in total, making it the largest accidental oil spill in history. It was surpassed only by the 1991 Persian Gulf spill in which Iraq intentionally spilled twice this amount.

The environmental impact occurred in four ecosystems: the offshore waters, inshore coastal waters, seabed and shoreline wetlands and beaches. The spill also inflicted serious economic and psychological damage on communities along the Gulf Coast that depend on tourism, fishing and drilling. President Obama called the BP oil spill 'the worst environmental disaster America has ever faced'.

Most of the oil has now evaporated or dissolved, but an estimated 10 million gallons remain on the sea floor, and gobs of oil can still be found nestled into marshes along the coast. There is still debate about the impact on wildlife. BP has claimed that there is no evidence of any 'significant long-term population-level impact to any species'. However, other scientists have cautioned that the full scope of the impact will not be known for some time. There is evidence that bottlenose dolphins in the Gulf of Mexico have been dying at more than twice the normal rate over the last five years.

Section 12.3 Activities

1. Define **a** *pollution* and **b** *environmental degradation*.
2. **a** With reference to Figure 12.26, describe the global distribution of deaths from urban air pollution.
   b Suggest reasons for the spatial variations you have identified.
3. Which industries are the largest polluters?
4. Write a brief explanation of Figure 12.29.
5. Explain the relationship illustrated by Figure 12.30.

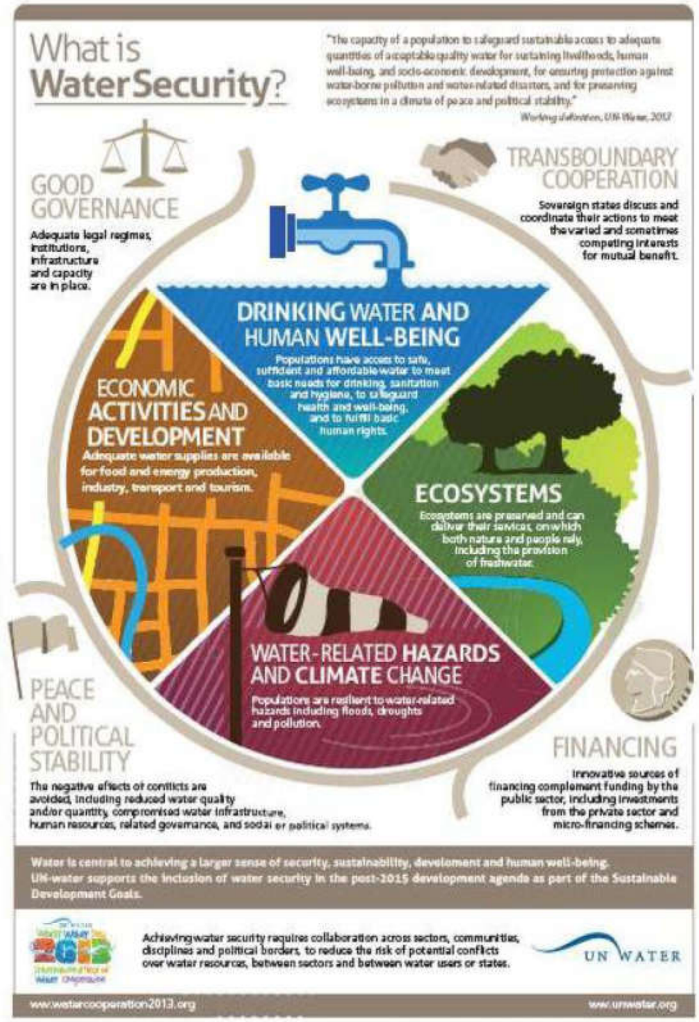
☐ Water: demand, supply and quality

The global water crisis

> According to the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, at least 1.8 billion people worldwide are estimated to drink water that is faecally contaminated. An even greater number drink water that is delivered through a system without adequate protection against sanitary hazards.
>
> *UN Water, 2014*

The longest a person can survive without water is about 10 days. All life and virtually every human activity needs water. It is the world's most essential resource and a pivotal element in poverty reduction. But for about 80 countries, with 40 per cent of the world's population, lack of water is a constant threat. And the situation is getting worse, with demand for water doubling every 20 years. In those parts of the world where there is enough water, it is being wasted, mismanaged and polluted (Figure 12.33) on a grand scale. In the poorest nations, it is not just a question of lack of water; the paltry supplies available are often polluted. The quality of drinking water is a major environmental determinent of health. **Water security** (Figure 12.34) has become a major issue in an increasing number of countries.

Figure 12.33 Polluted water – Christchurch, New Zealand



Source: www.unwater.org/fileadmin/user_upload/unwater_new/docs/water_security_poster_Oct2013.pdf

Figure 12.34 What is water security?

Securing access to clean water is a vital aspect of development.

- More than 840 000 people die each year from a water-related disease. While deaths associated with dirty water have been virtually eliminated from HICs, in LICs most deaths still result from water-borne disease.
- At any one time, half of the world's hospital beds are occupied by patients suffering from water-borne diseases.
- 750 million people around the world lack access to safe water – approximately one in nine people; 82 per cent of those who lack access to improved water live in rural areas, while just 18 per cent live in urban areas.
- In LICs, 70 per cent of industrial waste is dumped untreated into rivers and other water sources, which pollutes the usable water supply.
- Women and children spend 140 million hours a day collecting water.

Water scarcity has been presented as the 'sleeping tiger' of the world's environmental problems, threatening to put world food supplies in jeopardy, limit economic and social development and create serious conflicts between neighbouring drainage-basin countries. In the twentieth century, global water consumption grew six-fold, twice the rate of population growth. Much of this increased consumption was made possible by significant investment in water infrastructure, particularly dams and reservoirs affecting nearly 60per cent of the world's major river basins.

The UN estimates that two-thirds of world population will be affected by 'severe water stress' by 2025. The situation will be particularly severe in Africa, the Middle East and South Asia. The UN notes that already a number of the world's great rivers such as the Colorado in the USA are running dry, and that groundwater is also being drained faster than it can be replenished. Many major aquifers have been seriously depleted, which will present serious consequences in the future. In an effort to add impetus to global water advancement, the UN proclaimed the period 2005–15 as the International Decade for Action, 'Water for Life'.

The Middle East and North Africa face the most serious problems. Since 1972, the Middle East has withdrawn more water from its rivers and aquifers each year than is being replenished. Yemen and Jordan are withdrawing 30per cent more from groundwater resources annually than is being naturally replenished. Israel's annual demand exceeds its renewable supply by 15per cent. In Africa, 206million people live in water-stressed or water-scarce areas.

The Pilot Analysis of Global Ecosystems (PAGE), undertaken by the World Resources Institute, calculated water availability and demand by river basin. This analysis estimated that at present 2.3billion people live in water-stressed areas, with 1.7billion resident in water-scarce areas. The PAGE analysis forecasts that these figures will rise to 3.5billion and 2.4billion people respectively by 2025.

The link between poverty and water resources is very clear, with those living on less than $1.25 a day roughly equal to the number without access to safe drinking water. Improving access to safe water can be among the most cost-effective means of reducing illness and mortality (Figure 12.35). In LICs, it is common for water collectors, usually women and girls, to have to walk several kilometres every day to fetch water. Once filled, pots and jerry cans can weigh as much as 20kilograms. In urban areas in LICs, water is still often distributed by donkey and cart (Figure 12.36).

Figure 12.35 The narrow irrigation zone along the banks of the River Nile, Egypt

Figure 12.36 Water collection/distribution in central Asia

Since 1930, global population has increased from 2billion to over 7billion, putting ever-increasing pressure on the world's water supplies. However, it is not just the increase in population that is influencing the demand for water, but also rising per person usage in many countries. As households become more affluent, they use more water in an increasing number of different ways.

Millennium Development Goal 7, target 10, stated: 'Halve, by 2015, the proportion of people without sustainable access to safe water and basic sanitation'. Although this goal has been achieved, much remains to be done to improve water security in many parts of the world.

Water utilisation at the regional scale

Every year, 110000km³ of precipitation falls onto the Earth's land surface. This would be more than adequate for the global population's needs, but much of it cannot be captured and the rest is very unevenly distributed. For example:

- Over 60per cent of the world's population live in areas receiving only 25per cent of global annual precipitation.
- The arid regions of the world cover 40per cent of the world's land area, but receive only 2per cent of global precipitation.
- The Congo River and its tributaries account for 30per cent of Africa's annual runoff in an area containing 10per cent of Africa's population.

Figure 12.37 shows what happens to the precipitation reaching land surfaces. Green water is that part of total precipitation that is absorbed by soil and plants, then released back into the air. As such, it is unavailable for human use. However, green water scarcity is the classic cause of famine. Green water accounts for 61.1per cent of total precipitation. The remaining precipitation, known as blue water, collects in rivers, lakes, wetlands and groundwater. It is available for human use before it evaporates or reaches the ocean. As Figure 12.37 shows, only 1.5per cent of total precipitation is directly used by people.

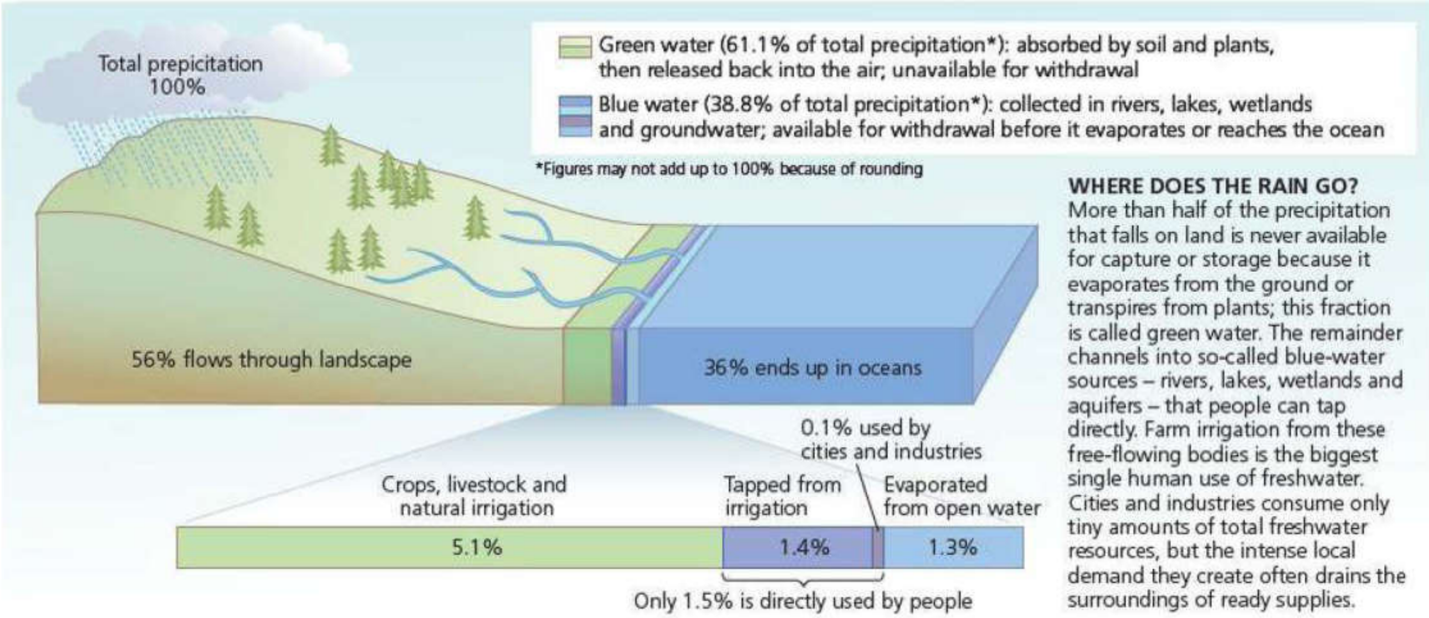


Figure 12.37 Where does the rain go?

Total world blue water withdrawals are estimated at 3390 km³, with 74 per cent for agriculture, mostly irrigation (Figure 12.38). About 20 per cent of this total comes from groundwater. Although agriculture is the dominant water user, industrial and domestic uses are growing at faster rates. Demand for industrial use has expanded particularly rapidly.

The amount of water used by a population depends not only on water availability but also on levels of urbanisation and economic development. As global urbanisation continues, the demand for potable water in cities and towns will rise rapidly. In many cases, demand will outstrip supply.

In terms of agriculture, more than 80 per cent of crop evapotranspiration comes directly from rainfall, with the remainder from irrigation water diverted from rivers and groundwater. However, this varies considerably by region. In the Middle East and North Africa, where rainfall is low and unreliable, more than 60 per cent of crop evapotranspiration originates from irrigation.

Figure 12.39 contrasts water use in HICs and LICs/MICs. In the latter, agriculture accounts for over 80 per cent of total water use, with industry using more of the remainder than domestic allocation. In the HICs, agriculture accounts for slightly more than 40 per cent of total water use. This is lower than the amount allocated to industry. As in LICs/MICs, domestic use is in third place.

As LICs industrialise and urban-industrial complexes expand, the demand for water grows rapidly in the industrial and domestic sectors. As a result, the competition with agriculture for water has intensified in many countries and regions. This is a scenario that has already played itself out in many HICs, where more and more difficult decisions are having to be made on how to allocate water.

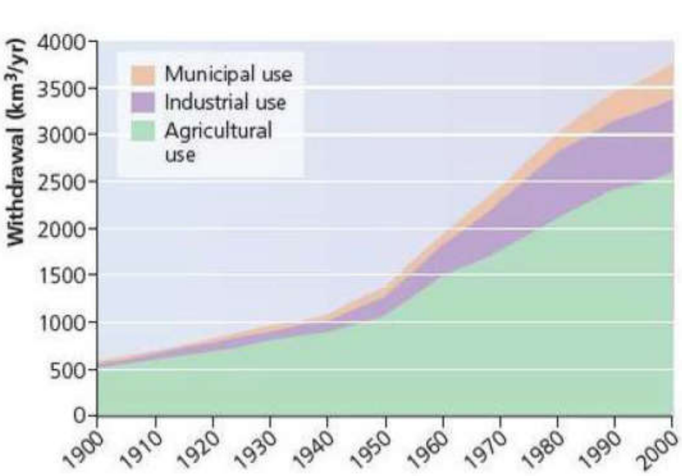


Figure 12.38 Global water use (agriculture, industry, domestic), 1900–2000

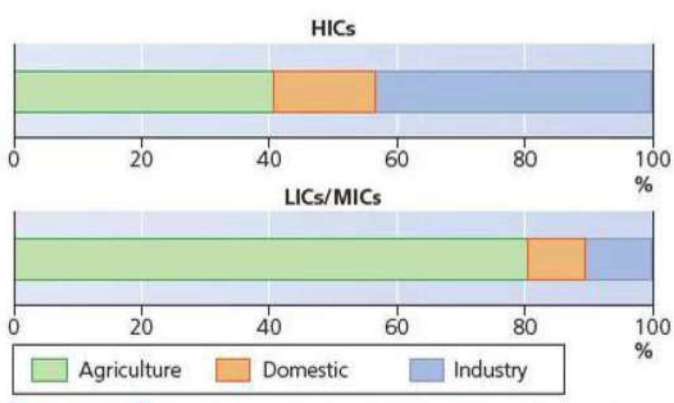


Figure 12.39 Water for agricultural, industrial and domestic uses in HICs and LICs/MICs

Large variations in water allocation can also exist within countries. For example, irrigation accounts for over 80 per cent of water demand in the west of the USA, but only about 6 per cent in the east.

The environmental and human factors affecting water scarcity

The world's population is increasing by about 80 million a year. This converts to an increased demand for freshwater of around 64 billion m³ per year, which equates to the total annual flow rate of the River Rhine.

A country is judged to experience water stress when water supply is below 1700 m³ per person per year. When water supply falls below 1000 m³ per person a year, a country faces water scarcity for all or part of the year. These concepts were developed by the Swedish hydrologist Malin Falkenmark.

Water scarcity is to do with the availability of potable water. **Physical water scarcity** is when physical access to water is limited. This is when demand outstrips a region's ability to provide the water needed by the population. It is the arid and semi-arid regions of the world that are most associated with physical water scarcity. Here, temperatures and evapotranspiration rates are very high and precipitation low. In the worst-affected areas, points of access to safe drinking water are few and far between

However, annual precipitation figures fail to tell the whole story. Much of the freshwater supply comes in the form of seasonal rainfall (Figure 12.40), as exemplified by the monsoon rains of Asia. India gets 90 per cent of its annual rainfall during the summer monsoon season from June to September. National figures can also mask significant regional differences. Analysis of the supply and demand situation by river basin can reveal the true extent of such variations. For example, the USA has a relatively high average water-sufficiency figure of 8838 m³ per person a year. However, the Colorado river basin has a much lower figure of 2000, while the Rio Grande river basin is lower still at 621 m³ per person a year.

Figure 12.40 The dried-up bed of the Rio Oja, northern Spain

However, in increasing areas of the world, physical water scarcity is the result of human activity, largely overuse. Examples of physical water scarcity include:

- Egypt has to import more than half of its food because it does not have enough water to grow it domestically.
- The Murray–Darling basin in Australia has diverted large quantities of water to agriculture.
- The Colorado river basin in the USA once had an abundant supply of water but resources have been heavily overused, leading to very serious physical water scarcity downstream.

Figure 12.41 shows these regions and other parts of the world that suffer from physical water scarcity.

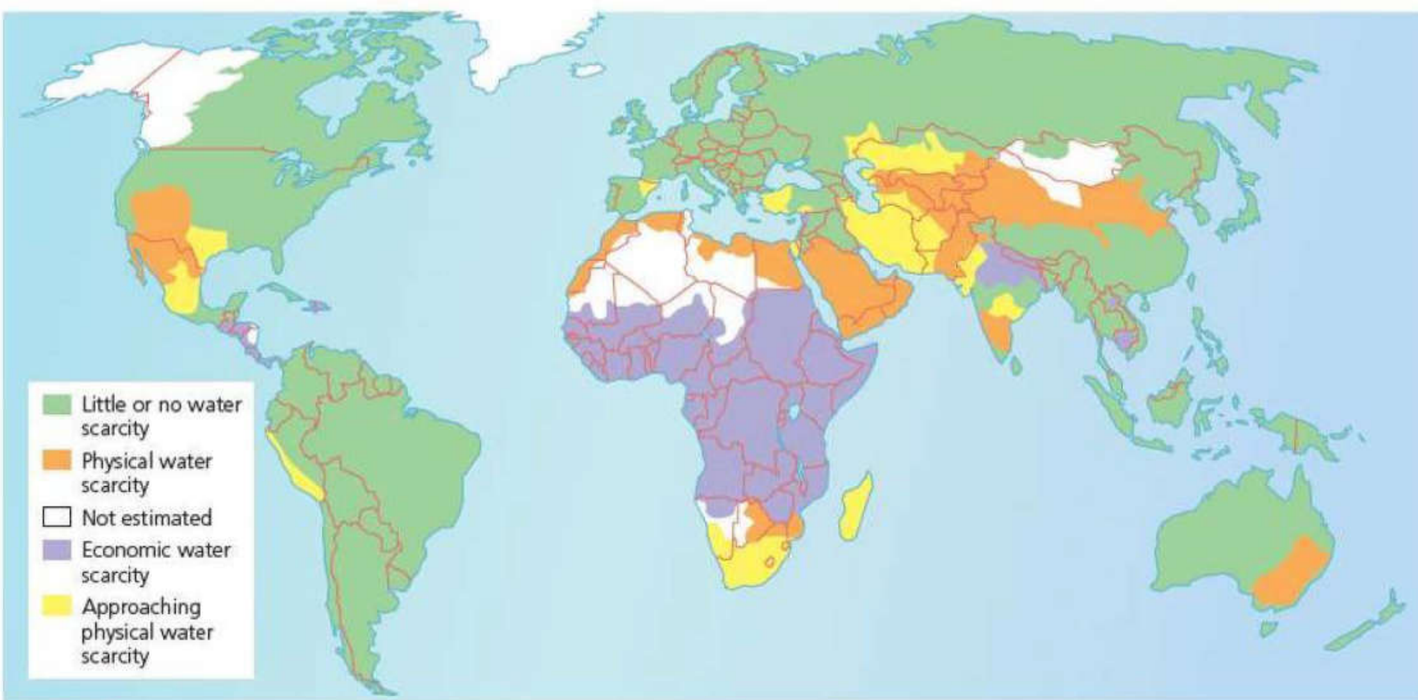


Figure 12.41 Physical water scarcity and economic water scarcity

Economic water scarcity exists when a population does not have the necessary monetary means to utilise an adequate supply of water. The unequal distribution of resources is central to economic water scarcity, where the crux of the problem is lack of investment. This occurs for a number of reasons, including political and ethnic conflict. Figure 12.41 shows that much of Sub-Saharan Africa is affected by this type of water scarcity.

Scientists expect water scarcity to become more severe, largely because:

- the world's population continues to increase significantly
- increasing affluence is inflating the per person demand for water
- there is an increasing demand for production of biofuels – biofuel crops are heavy users of water
- climate change is increasing aridity and reducing supply in many regions
- many water sources are threatened by various forms of pollution.

The Stockholm International Water Institute has estimated that each person on Earth needs a minimum of 1000 m^3 of water per year for drinking, hygiene and growing food for sustenance. Whether this water is available depends largely on where people live on the planet, as water supply is extremely inequitable. For example, major rivers such as the Yangtze, Ganges and Nile are severely overused and the levels of underground aquifers beneath major cities such as Beijing and New Delhi are falling.

In many parts of the world, the allocation of water depends largely on the ability to pay. A recent article in *Scientific American*, entitled 'Facing the freshwater crisis', quotes an old saying from the American West: 'Water usually runs downhill, but it always runs uphill to money' – meaning that poorer people and non-human consumers of water, the fauna and flora of nearby ecosystems, usually lose out when water is scarce.

Virtual water

The importance of the concept of **virtual water** is being increasingly recognised. Virtual water is the amount of water that is used to produce food or any other product and is thus essentially embedded in the item. One kilogram of wheat takes around 1000 litres of water to produce, so the import of this amount of wheat into a dry country saves that country this amount of water. According to *Scientific American* (August 2008, page 34), 'The virtual water concept and expanded trade have also led to the resolution of many international disputes caused by water scarcity. Imports of virtual water in products by Jordan have reduced the chance of water-based conflict with its neighbour Israel, for example.'

The size of global trade in virtual water is more than 800 billion m^3 of water a year. This is equivalent to the flow of ten Nile Rivers. Greater liberalisation of trade in agricultural products would further increase virtual water flows.

Section 12.3 Activities

1 How far do you think you could walk carrying water weighing 20 kilograms?
2 Write a brief explanation of the information presented in Figure 12.37.
3 Draw a table to show how global water use changed for municipal, industrial and agricultural uses for the following years: 1900, 1940, 1980, 2000 (Figure 12.38).
4 Describe and explain the different ways in which water is used in **a** HICs and **b** LICs.
5 **a** Explain the difference between physical water scarcity and economic water scarcity.
b Describe and attempt to explain the spatial variations shown in Figure 12.41.

The degradation of rural environments

Rural environments supply humankind with most of its food and gene pool and contain the vast majority of the world's forested land. However, rural areas all around the world have been degraded at a rapid rate over the last century. This has been due primarily to population growth and increasing pressures on the land, although urban activities through processes such as climate change can also have profound consequences for rural environments.

The UN Food and Agriculture Organization defines soil degradation as 'a change in the soil health status resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries'. Soil degradation involves both the physical loss (erosion) and the reduction in quality of topsoil associated with nutrient decline and contamination. It impacts significantly on agriculture and also has implications for the urban environment, pollution and flooding.

Globally, it is estimated that 2 billion hectares of soil resources have been degraded. This is equivalent to about 15 per cent of the Earth's land area. Such a scale of soil degradation has resulted in the loss of 15 per cent of world agricultural supply in the last 50 years. Some scientists consider this to be a 'slow-motion disaster'. In temperate areas, much soil degradation is a result of market forces and the attitudes adopted by commercial farmers and governments. In contrast, in the tropics much degradation results from high population pressure, land shortages and lack of awareness. The greater climate extremes and poorer soil structures in tropical areas give greater potential for degradation in such areas compared to temperate latitudes. This difference has been a significant factor in development or the lack of it.

The main cause of soil degradation is the removal of the natural vegetation cover, leaving the surface exposed to the elements. Figure 12.42 shows the human causes of degradation, with deforestation and overgrazing as the two main problems. The resulting loss of vegetation cover is a leading cause of wind and water erosion.

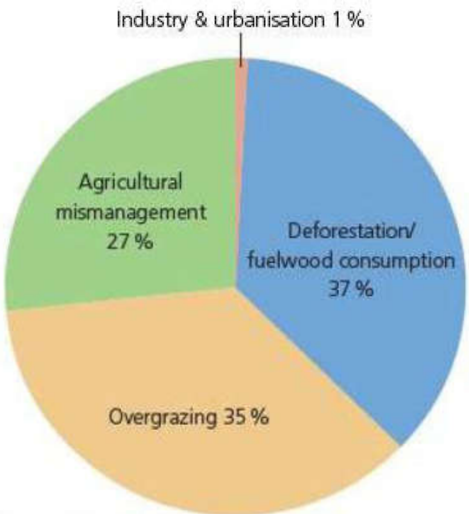


Figure 12.42 Causes of land degradation

Deforestation occurs for a number of reasons, including the clearing of land for agricultural use, for timber and for other activities such as mining. Such activities tend to happen quickly, whereas the loss of vegetation for fuelwood, a massive problem in many LICs, is generally a more gradual process. Deforestation means that rain is no longer intercepted by vegetation, with rainsplash loosening the topsoil and leaving it vulnerable to removal by overland flow.

Overgrazing is the grazing of natural pastures at stocking intensities above the livestock carrying capacity. Population pressure in many areas and poor agricultural practices have resulted in serious overgrazing. This is a major problem in many parts of the world, particularly in marginal ecosystems. The process occurs in this way:

1. Trampling by animals (and humans) damages plant leaves.
2. Some leaves die away, reducing the ability of plants to photosynthesise.
3. Now there are fewer leaves to intercept rainfall and the ground is more exposed.
4. Plant species sensitive to trampling quickly disappear.
5. Soil begins to erode when bare patches appear. Trampling will have compacted the soil and damaged its structure.
6. Loose surface-soil particles are the first to be carried away, either by wind or water.
7. The loss of soil structure means that less water can infiltrate to the lower soil horizons. The growth rate of plants is reduced and it is more difficult for damaged plants to recover.

Agricultural mismanagement is also a major problem due to a combination of lack of knowledge and the pursuit of short-term gain against consideration of longer-term damage. Such activities include shifting cultivation without adequate fallow periods, absence of soil conservation measures, cultivation of fragile or marginal lands, unbalanced fertiliser use and the use of poor irrigation techniques.

Soil degradation is more directly the result of:

- **erosion by wind and water** – these two agents of erosion account for approximately 80 per cent of the world's degraded landscapes
- **physical degradation** – loss of structure, surface sealing and compaction
- **chemical degradation** – through various forms of pollution; changes in pH, acidification and salinisation are examples of chemical degradation
- **biological degradation** – through loss of organic matter and biodiversity
- **climate and land-use change** – which may accelerate the factors above.

The environmental and socio-economic consequences of soil degradation are considerable. Such consequences can occur with little warning as damage to soil is often not perceived until it is far advanced.

The increasing world population and the rapidly changing diets of hundreds of millions of people as they become more affluent are placing more and more pressure on land resources. Some soil and agricultural experts say that a decline in long-term soil productivity is already seriously limiting food production in LICs.

The loss of the ability of degraded soils to store carbon is receiving significant attention. Over the last 50 years or so, global soils have lost about 100 billion tonnes of carbon, in the form of carbon dioxide, to the atmosphere, due to the depletion of soil structure.

The UN's Food and Agriculture Organization lists five root causes of unsustainable agricultural practices and degradation of the rural environment (Figure 12.43).

- **Policy failure**
  Leading among the causes of unsustainable agriculture are inadequate or inappropriate policies, which include pricing, subsidy and tax policies, which have encouraged the excessive and often uneconomic use of inputs, such as fertilisers and pesticides and the overexploitation of land. They may also include policies that favour farming systems that are inappropriate both to the circumstances of the farming community and to available resources.
- **Rural inequalities**
  Rural people often know best how to conserve their environment, but they may need to overexploit resources in order to survive. Meanwhile, commercial exploitation by large landowners and companies often causes environmental degradation in pursuit of higher profits.
- **Resource imbalances**
  Almost all of the future growth in the world's population will be in LICs, and the biggest increases will be in the poorest countries of all – those least equipped to meet their own needs or invest in the future.
- **Unsustainable technologies**
  New technologies have boosted agricultural production worldwide, but some have had harmful side-effects that must be contained and reversed, such as resistance of insects to pesticides, land degradation through wind or water erosion, nutrient depletion, poor irrigation management and the loss of biological diversity.
- **Trade relations**
  As the value of raw materials exported by LICs has fallen, their governments have sought to boost income by expansion of crop production and timber sales that have damaged the environment.

Source: www.fao.org

Figure 12.43 Five root causes of unsustainable practices

The environmental impact of capital-intensive farming

There is a growing realisation that the modes of production, processing, distribution and consumption that prevail – because in the short- to medium-term they are the most profitable – are not necessarily the most healthy or the most environmentally sustainable (Figure 12.44). In many parts of the world, agro-industrialisation is having a devastating impact on the environment, causing:

- deforestation
- land degradation and desertification
- salinisation and contamination of water supplies
- air pollution
- increasing concerns about the health of long-term farm workers

Figure 12.44 Gobi desert – climate change has resulted in further land degradation

- landscape change
- declines in biodiversity.

About a third of the world's farmland is already affected by salinisation, erosion or other forms of degradation.

The global cattle population is currently around 1.5 billion. The pasture required amounts to about a third of all the world's agricultural land. A further third of this land is taken up by animal feedcrops. An estimated 1.3 billion people are employed in the livestock industry. The balance between livestock and grass is sustainable at present, but as the demand for meat increases, the pressures that cattle make on the land may well soon exceed supply. More cattle means more manure. Manure is often used to restore depleted soil, but can lead to pollution by heavy metals such as cadmium, nickel, chromium and copper.

In 2000, annual global meat consumption was 230 million tonnes. The forecast for 2050 is 465 million tonnes. There is a strong relationship between meat consumption and rising per person incomes (Figure 12.45), although anomalies do occur due to cultural traditions. It is no coincidence that many committed environmentalists are vegetarian. A study at the University of Chicago calculated that changing from the average American diet to a vegetarian one could cut annual emissions by almost 1.5 tonnes of carbon dioxide.

Figure 12.45 Meat consumption and income

Large-scale farming has been expanding geographically into a number of fragile environments, particularly into areas of rainforest. *The State of the World's Forests 2007*, published by the FAO, reported that between 1990 and 2005, the world's total forest area was reduced by 3 per cent. This is a rate of 7.3 million hectares per year.

Mainly because of the uniformity required by large food companies, important breeds of livestock are becoming extinct. The FAO's *State of the World's Animal Genetic Resources* report stated that at least one livestock breed a month had been lost over the previous seven years. Food scientists are concerned about this trend as genetic resources are the basis of food security.

Agro-industrialisation is characterised by large areas of monoculture that, among other things, leaves crops more vulnerable to disease due to the depletion of natural systems of pest control. Monoculture results in reliance on pesticides, which in turn causes a downward environmental cycle (Figure 12.46).

Figure 12.46 Land degradation in southern Italy

Poverty and rural degradation

The interactions shown in Figure 12.47 illustrate certain poverty-environment processes where poor households are 'compelled' to degrade environmental resources. However, this should not hide the fact that much environmental degradation is caused by large-scale commercial operations and government policy. There are also an increasing number of sustainable schemes being practised in poor rural areas.

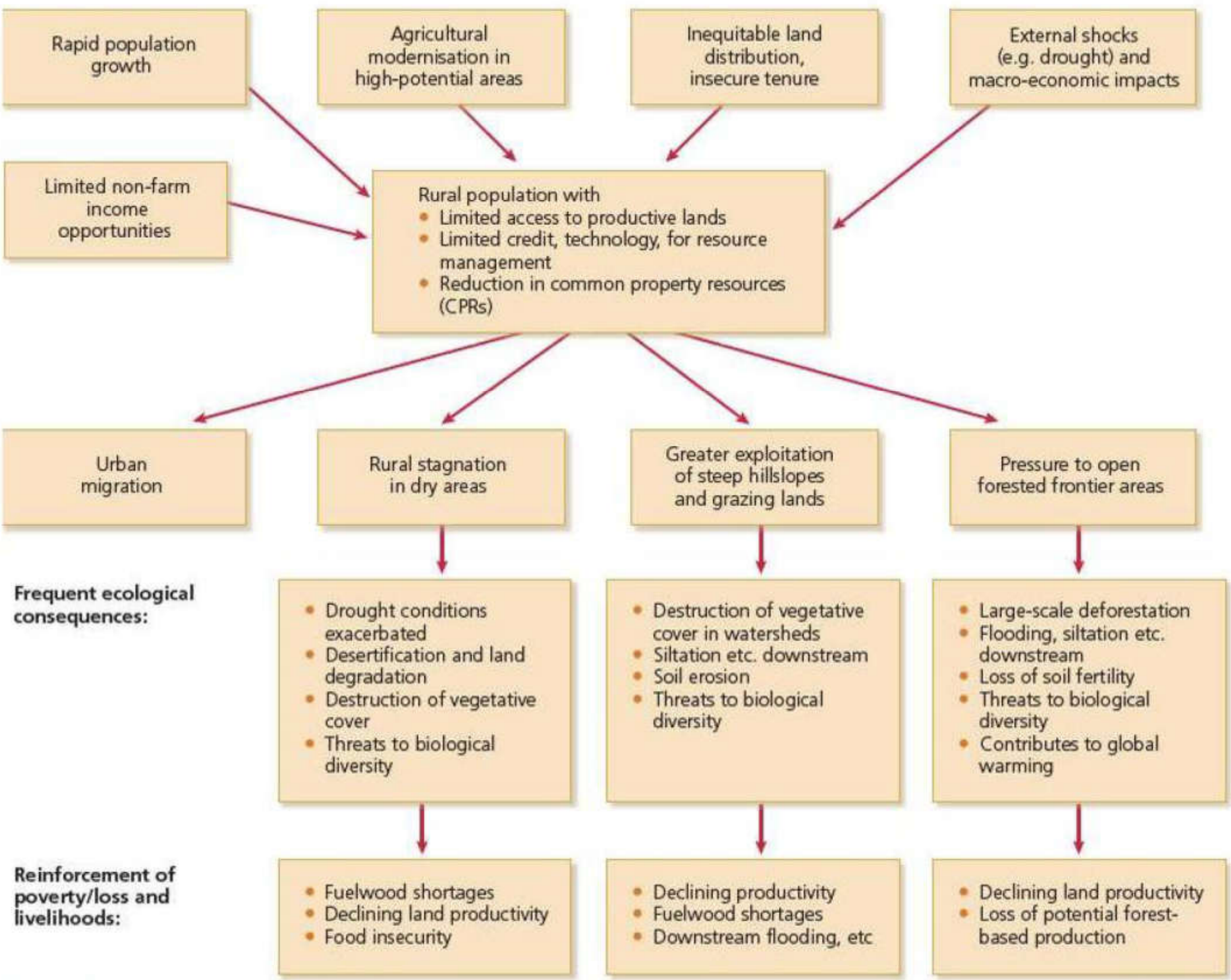


Figure 12.47 Poverty–environment links

Poor households can suffer significantly from the actions of large-scale rural operations. They may be pushed onto more marginal lands by logging, ranching or mining operations. Government policy can also have a significant negative effect on the poor, for example if land or tree tenure rights are insecure.

Urban/rural impact

Urban areas can affect the environmental degradation of their rural surroundings in a number of ways. For example, untreated wastewater is a major pollutant of rivers, which can contaminate estuaries and coastal fishing areas, and can pollute the drinking-water supplies of rural communities downstream. Urban use of groundwater can result in a depletion of the aquifer to the detriment of small farmers who rely on shallow wells. In arid areas, cities many kilometres inland can cause saltwater intrusion under coastal areas as a result of groundwater pumping. On a larger scale, the huge urban-industrial complexes of the world are the main cause of climate change, which is having an adverse impact on the entire planet.

Section 12.3 Activities

1. Discuss the five root causes of unsustainable practices set out in Figure 12.43.
2. Describe and explain the relationship between per person income and per person meat consumption illustrated in Figure 12.45. Suggest reasons for significant anomalies. What statistical technique could you use to assess the relationship between these two variables?
3. Produce a 100-word summary of the relationships illustrated in Figure 12.47.

The degradation of urban environments

The environmental quality of urban areas has a huge impact on their populations (Figure 12.48). The degradation of urban environments occurs mainly through urbanisation, industrial development and inadequate infrastructure. Few urban residents can escape the effects of poor air and water quality, inadequate sanitation, a lack of proper solid waste management and the improper storage and emission of hazardous substances. Figure 12.49 shows how urban environmental problems can act at different scales, affecting households, communities and cities.

Figure 12.48 London's low-emission zone

Amenity loss	Traffic congestion	**City**	Loss of heritage and historical buildings	Reduced property and building values
Accidents and disasters	Polluted land	**Community**	Inappropriate and inadequate technology use	Inadequate tax/financial revenues
Flooding and surface drainage	Garbage dumping	**Household** Household health, garbage generation, air/water/noise pollution, spread of diseases	Lack of understanding of environmental problems	Lack of, and inappropriate, laws and legislation
Toxic and hazardous wastes/dumps	Flooding	Noise pollution	Natural disasters	High living densities
Loss of agricultural land and desertification	Air pollution	Water pollution	Inadequate supply and transmission loss of electricity	Misguided urban, government and management practices

Figure 12.49 The scales of urban environmental problems

The relationship between the urban poor and the environment is different from that between the rural poor and the environment. The urban poor are particularly affected by poor environmental services such as sub-standard housing, a lack of sanitation and other aspects of urban poverty.

Case Study: Urban degradation in Delhi

In 2014, the World Health Organization stated that Delhi was the most air-polluted city in the world. The WHO ranking was based on the concentration of $PM_{2.5}$ particles in a study of 1600 cities across 91 countries. These very fine particles, less than 2.5 micrometres in diameter, are linked to increased rates of heart disease, lung cancer and chronic bronchitis. According to the WHO, Delhi had an average $PM_{2.5}$ level of 153, about ten times that of London, UK. The WHO says that air pollution is the fifth biggest cause of death in India. However, Indian and Delhi officials have disputed the WHO findings, feeling that the analysis has overestimated the problem in Delhi compared to polluted cities in other countries such as Beijing.

The National Capital Region (NCR) of Delhi has grown rapidly in recent decades. Delhi now covers an area of approximately 900 km^2. The population of the NCR, which was estimated at 17.8 million in 2014, is expected to reach 22.5 million in 2025. Such a fast rate of expansion has increased the environmental impacts of transportation, industrial activity, power generation, construction, domestic activities and waste generation. Thus, Delhi's pollution problems have a wide variety of causes, as Table 12.13 shows.

- Transport is the main source of $PM_{2.5}$, NO_x and VOC emissions.
- Road dust is the main source of PM_{10} emissions.
- Power plants are responsible for over half of SO_2 emissions and almost 30 per cent of CO_2 emissions.

Economic growth has created an increasing number of people in the middle-class income bracket who have aspired to own their own car. However, it is not just private cars that have significantly increased in number, but also taxis, autorickshaws, buses and business vehicles of all kinds. There are now an estimated 7.2 million vehicles on Delhi's roads – about twice the number in 2000. Traffic speeds have fallen as the city has struggled to improve its road infrastructure to meet increasing demand. As traffic speeds have fallen idling time has increased, resulting in higher levels of air pollution.

Pollution levels are particularly high during winter due to:

- **night-time heating needs** – the poor in Delhi use open fires to keep warm in winter
- **seasonal weather conditions** – which trap pollutants very close to the ground.

Delhi also suffers from dust blown in from the deserts of the western state of Rajasthan.

Water pollution and a lack of solid-waste treatment facilities have caused serious damage to the Yamuna River. Roughly half of all the city's raw sewage goes straight into the river: 22 drains flow into the Yamuna from the city, containing industrial waste as well as domestic waste. Pickling, dyeing and electroplating factories are major sources of water pollution.

Surveys have shown that people in Delhi are also concerned about noise and light pollution. Residents perceive levels of both to be high. A study published in 2013 warned that very high levels of noise pollution were causing age-related hearing loss 15 years earlier than normal. Among other environmental issues, residents are also extremely critical of garbage disposal in the city – with very good reason (Figure 12.50).

Table 12.13 The sources of emissions in Delhi (tonnes/year and percentage), 2010

	$PM_{2.5}$	PM_{10}	SO_2	NO_x	CO	VOC
Transport	17750 (26%)	23800 (18%)	950 (2%)	329750 (67%)	421450 (28%)	208900 (63%)
Domestic	7300 (10%)	8800 (7%)	2050 (5%)	2350 (1%)	161200 (10%)	18300 (6%)
Diesel	3200 (5%)	4300 (3%)	1050 (3%)	81300 (16%)	85100 (6%)	31600 (9.49%)
Brick kilns	9250 (13%)	12400 (9%)	4000 (11%)	6750 (1%)	171850 (11%)	24200 (7%)
Industries	9000 (13%)	12650 (9%)	8500 (23%)	41500 (8%)	219600 (14%)	13250 (4%)
Construction	2450 (3%)	8050 (6%)	100 (1%)	2150 (1%)	2700 (1%)	50 (0.01%)
Waste burning	3850 (6%)	5450 (4%)	250 (1%)	1450 (1%)	20050 (1%)	1600 (0.5%)
Road dust	6300 (9%)	41750 (31%)	–	–	–	–
Power plant	10150 (15%)	16850 (13%)	20250 (54%)	27200 (5%)	442150 (29%)	34900 (10%)
Total	**69050 (100%)**	**133900 (100%)**	**37000 (100%)**	**492250 (100%)**	**1524050 (100%)**	**332700 (100%)**

Source: www.urbanemissions.info

DELHI MAY DROWN IN ITS OWN WASTE

Adapted (slightly) from Darpan Singh, *Hindustan Times*, 30 April 2013

Growing by heaps and mounds, Delhi's garbage crisis may soon reach its breaking point.

Three of the four stinking waste mountains (landfills) are long overdue for closure and there are no fresh landfills available to take in the current daily discard of 9000 tonnes. By 2020, the Capital needs an additional area of 28 sq km to dump 15 000 tonnes of garbage daily.

Since as much as 85 per cent of the city doesn't have a formal door-to-door trash pick-up system, the emerging scenario is both worrisome and scary.

The 2500-odd filthy community bins (*dhalaos*) that serve as secondary collection centres for the three municipal bodies in thousands of colonies will start overflowing, and garbage will spill on to the streets. Residents will have no option but to start throwing waste out, making Delhi drown in its own discard.

People in Delhi are bitterly opposed to new landfills coming up in their neighbourhood as they have seen the authorities did not maintain the past ones scientifically, turning them into massive, polluting heaps. The black thick liquid, leachate, created when rainwater filters down through the landfill, has made the soil highly toxic. Rainwater runoff goes into surface water drains while methane poisons the air.

Despite court intervention, the government and civic agencies have failed to find a way forward. The civic bodies have now told the Delhi high court that 'since there's no other option, we have been forced to put human life and property at risk'.

Delhi's non-dumping options to manage waste have also shrunk drastically. Burning waste no longer seems viable because of environmental concerns and poor segregation of waste. Compost plants are not doing well because manure doesn't sell, and again becomes garbage.

As much as 50 per cent of the waste is fit for composting. About 30 per cent of it can be recycled. Effective segregation at source, in transit and during disposal, will mean only 20 per cent of the refuse is needed to be sent to the landfill site. This will also mean a cleaner city with fewer dhalaos, garbage trucks and longer lifespan for landfills. But instead of proper segregation, only random picking continues.

Either private sweepers, who snap up the most sought-after refuse, or residents themselves take waste to *dhalaos*. There, rag-pickers slog through the muck to hunt for recyclable materials.

When waste is taken from dhalaos to landfills, another set of trash-pickers collect what their street counterparts miss, completing a cycle of 'illegal' segregation.

Civic bodies blame residents for not segregating waste but what's the point when everything will eventually be mixed-up? Segregation by residents will only work when the corporations have a complete door-to-door waste collection system and trash pickups have separate containers for dry and wet waste.

Delhi has miserably failed to manage its waste load. Only 15 per cent of R1350 crore that the three corporations spend on waste management and sanitation is spent on actual disposal. The rest goes into collection and transportation.

The authorities must ensure segregation and promote composting and recycling. They must quantify waste generation for setting effective reduction targets. But don't wait for the authorities to do everything. From segregation, recycling to composting — you can make a difference. And, yes, consume and waste less. Now is the time.

Figure 12.50 Delhi's domestic waste problem

Thousands of people live without adequate water supply and sanitation. Many parts of the city have no piped water connections and depend on tankers to deliver water. This affects almost 25 per cent of Delhi's population. About half of the water flowing through Delhi's water pipes is lost through leakage. A study published in 2012 stated that nearly 60 per cent of Delhi's slums did not have sewerage facilities.

Tackling air pollution

In 2014, the Indian environment ministry launched a National Air Quality Index that will rank 66 Indian cities. It will give real time information of air quality, to put pressure on local authorities to take concrete steps to reduce pollution. The index will provide associated health risks in a colour-coded manner that can be understood by everyone.

Investment in public transport has been slow to develop in Delhi. The Delhi Metro Rail (DMR) only opened in December 2002 with an 8.3 kilometre rail line, and has since been extended to 190 kilometres with the completion of Phase II in 2011. Construction of Phase III is now underway, to add a further 103 kilometres. Another significant development has been the Delhi bus rapid transit (BRT), which opened along a 5.6 kilometre initial corridor in 2008.

Shutting coal power plants, promoting motorless transport and imposing strict penalties for those violating pollution control norms are among the suggestions that the government is looking at to improve the air quality in the city over the next five years.

The impact of rural areas

Runoff from fertilisers and pesticides can contaminate downstream urban water supplies. Deforestation, watershed degradation and soil eroding-practices can exacerbate flood–drought cycles. Deteriorating conditions in rural areas can give added impetus to rural–urban migration, placing additional pressures on the urban environment. This is part of a process known as the 'urbanisation of poverty'.

Section 12.3 Activities

1. Discuss the scales of urban environmental problems illustrated by Figure 12.49.
2. Outline one example of urban degradation in Delhi.
3. How can the activities of rural areas have an impact on urban environmental degradation?

☐ Constraints on improving degraded environments

There are numerous constraints on improving the quality of degraded environments:

- In many LICs, population growth continues at a high rate, putting increasing pressure on already fragile environments.
- High rates of rural–urban migration can lead to rapidly deteriorating environmental conditions in large urban areas, at least in the short term.
- Environmental hazards, often made worse by climate change, present an increasing challenge in some world regions. In many regions, natural hazards have increased in scale and unpredictability.
- Poor knowledge about the environmental impact of human actions is a significant factor in many locations where perhaps moderate adaptation of human behaviour could bring about beneficial changes.
- Poor management at both central and local government levels may result in problems that can at least be partially rectified not being addressed. The quality of governance has been recognised as a key factor in the general development process.
- Many degraded environments require substantial investment to bring in realistic solutions. Such finance is beyond the means of many poor countries. However, there may be a choice between low-cost and high-cost schemes, as Table 12.14 illustrates.
- Civil war has put back development by decades in some countries. Land mines that have yet to be cleared have put large areas off limits in some countries.

Corruption and crime can also reduce the effectiveness of schemes to reduce environmental degradation. An article in *The Guardian* newspaper in October 2009 stated that a revolutionary UN scheme to cut carbon emissions by paying poorer countries to preserve their forests was a recipe for corruption,

Table 12.14 Technical and institutional costs in resource management by and for poor people

	High institutional costs	Low institutional costs
Relatively high technical costs	• Large-scale irrigation • Arid or semi-arid land reforestation or pasture improvement • Sodic or saline land reclamation • Mangrove reforestation • Integrated river-basin management • Many transboundary resources, e.g. international rivers, air quality • Resettlement schemes • Water-pollution reduction programmes • Rural road maintenance • Ocean fisheries management	• Small-scale hill irrigation • Food crop systems on difficult soils • Localised water harvesting structures • Centralised provision of energy services • Solar energy for individual households • Pipe sewer systems • Emissions reduction devices • Improved public transport
Relatively low technical costs	• Aquifer management • Protection of critical areas • Coastal fisheries management • Coral-reef management • Pasture management • Land-reform programmes • Integrated pest management • Wild-game management	• Treadle pump irrigation • Humid tropics reforestation • Small water harvesting systems • Joint forest management regimes • Improved cooking stoves and cooking energy for poor families • Sloping agricultural land technology (SALT) • Small-scale quarrying • Household-based sanitation systems

Source: UNDP

and without strong safeguards could be hijacked by organised crime. Many countries and organisations have strongly backed the UN plans to expand the global carbon market to allow countries to trade the carbon stored in forests.

The protection of environments at risk

Environments at risk can be protected in various ways. At the most extreme, human activity and access can be totally banned, such as in Wilderness Areas; or extremely limited, as is usually the case in National Parks. However, in many areas it is usually necessary to sustain significant populations and rates of economic activity, particularly in LICs. In these cases, various types of sustainable-development policies need to be implemented. Individual environments can be assessed in terms of:

- **needs** – what needs to be done to reduce environmental degradation as far as possible without destroying the livelihoods of the resident population?
- **measures** – what are the policies and practices that can be implemented to achieve these aims at various time scales?
- **outcomes** – how successful have these policies been at different stages of their implementation? Have policies been modified to cope with initially unforeseen circumstances?

An example of an endangered environment is Ecuador's Andean cloud forests. The Andean Corridor Project aims to protect the vital ecosystems of this diversity hotspot. Four reserves totalling 142000 hectares have already been created and there are plans to add more reserves to protect the forests and wildlife from human activity.

Sometimes degraded environments cross international borders and effective action requires close cooperation between countries. Degradation in one country, for example the large-scale removal of forest cover in Nepal, can have severe implications for a country downstream of a river system, in this case India.

Section 12.3 Activities

1 Discuss the constraints on improving the quality of degraded environments.
2 Write a brief summary of the framework presented in Table 12.14.

12.4 The management of a degraded environment

Case Study: Namibia – community development

Namibia, in south-west Africa, is a very sparsely populated country with a generally dry climate. Almost 29 per cent of its 2.3 million people live below the international poverty line of $1.25 a day. Environmental degradation and sustainability are significant issues in its marginal landscapes, with the government attempting to tackle these issues and reduce poverty at the same time. The causes of degradation have been mainly uncontrolled exploitation by a low-income population forced to think only in the short term in order to survive, and lack of management at all levels of government in earlier years. As the degradation process intensified, the government, assisted by international agencies, identified the problems and put in place a significant strategy.

Namibia's Communal Conservancy Programme (Figure 12.51) is regarded as a successful model of community-based natural resource management, with an improving record for wildlife numbers and poverty reduction. The programme gives rural communities unprecedented management and use rights over wildlife, which have created new incentives for communities to protect this valuable resource and develop economic opportunities in tourism.

Figure 12.51 Wildlife in a community conservancy in Namibia

The Conservancy Programme began in 1996 and there are now 64 community conservancies covering over 17 per cent of the country and embracing one in four of rural Namibians. **Community conservancies** (Figure 12.52) are legally recognised common property resource management organisations in Namibia's communal lands. The use rights given to conservancies include the rights to hunt, capture, cull and sell 'huntable game'. However, the government determines the overall culling rate and establishes quotas for protecting game used for trophy hunting.

An obvious sign of success is the significant increase in the numbers of wildlife in the conservancies after decades of decline. In the north-west conservancies, elephant numbers more than doubled between 1982 and 2000, and populations of oryx, springbok and mountain zebra rose tenfold. This improvement results from a decline in illegal hunting and poaching due to the economic value that conservancy communities now place on healthy wildlife populations.

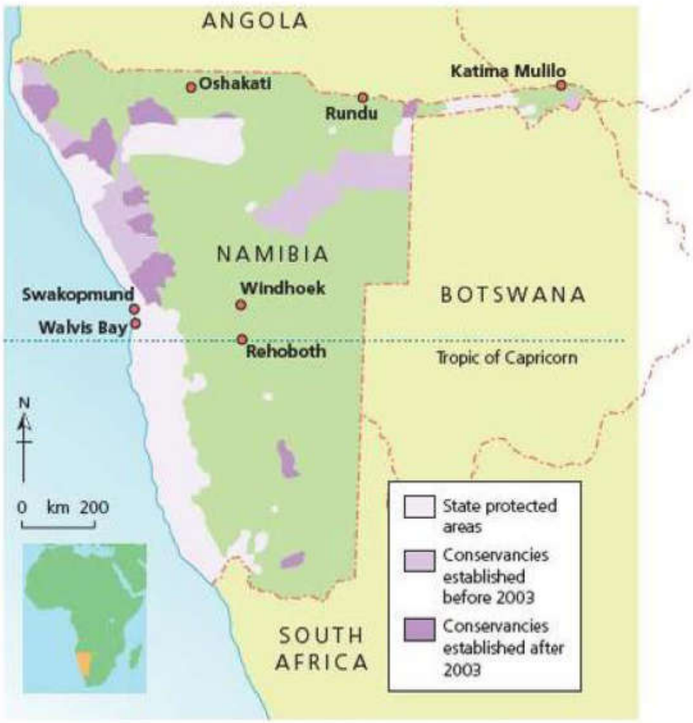


Figure 12.52 Namibia's community conservancies

The conservancies benefit from a number of 'new' economic activities, including:

- contracts with tourism companies
- selling hunting concessions
- managing campsites
- selling wildlife to game ranchers
- selling crafts.

These activities are in addition to traditional farming practices, which were usually at the subsistence level. The diversification of economic activity made possible by the Conservancy Programme has increased employment opportunities where few existed beforehand, and also raised incomes.

The significant participation of conservancy populations has been central to the design of the Programme. Conservancies are built around the willingness of communities to work collectively. Often, they form when neighbouring villages and tribal authorities agree to trace a boundary around their shared borders and manage the wildlife within this area. The Conservancy Programme has inbuilt flexibility that allows communities to choose diverse strategies for wildlife management and distributing benefits.

Support from and cooperation between a number of different institutions has been important to the development of the programme (Figure 12.53). Such institutions bring substantial experience and skills in helping conservancies to develop. Running skills training programmes has been an important aspect of such support. For example, communal conservancies are able to call on the experience of various NGOs for help and advice. This enables good practice in one area to be applied in other areas. The Namibian Community-based Tourism Association has been instrumental in helping communities negotiate levies and income-sharing agreements with tourism companies.

Organisation	Support activities
Legal Assistance Centre	Supplies legal advice and advocacy on issues related to community-based natural resource management (CBNRM)
Namibia Community-Based Tourism Association	Serves as an umbrella organisation and support provider for community-based tourism initiatives
Namibia NGO Forum	Represents a broad range of NGOs and community-based organisations
Namibia Nature Foundation Rössing Foundation	Provides assistance through grants, financial administration, technical support, fundraising, and monitoring and evaluation
Multi-disciplinary Research Centre	Provides training and materials for CBNRM partners
Namibia Development Trust	Centre of the University of Namibia provides research-related support
Centre for Research Information	Provides assistance to established and emerging conservancies in southern Namibia
Action in Africa – Southern Africa Development and Consulting	Provides research, developmental assistance, and market linkages for natural plant products

!NARA	Conducts capacity training in participatory, democratic management for conservancy communities and institutions supporting communities
Desert Research Foundation of Namibia	Researches arid land management, conducts participatory learning projects with communities about sustainable management, and engages policymakers to improve regulatory framework for sustainable development
Rural People's Institute for Social Empowerment	Provides assistance to established and emerging conservancies in southern Kunene and Erongo regions
Integrated Rural Development and Nature Conservation	A field-based organisation working to support conservancy development in Kunene and Caprivi regions
Nyae Nyae Development Foundation	Supports San communities in the Otjozondjupa region in the Nyae Nyae Conservancy
Ministry of Environment and Tourism	MET is not a formal member, but attends meetings and participates in NACSO working groups. Provides a broad spectrum of support in terms of policy, wildlife monitoring and management, and publicity.

Sources: MET 2005; NEEN 2004 a, b, c; Weaver 2007; Jones 2008 in Update 'Scaling up Namibia's community conservancies', p.32

Figure 12.53 Namibian Association of CBNRM Support Organisations (NACSO)

Although rural poverty remains significant in Namibia, the Conservancy Programme has resulted in substantial progress, with income rising year on year. Table 12.15 shows the detailed breakdown of conservancy-related income in 2006. In 2006, conservancy income reached nearly N$19 million (US$1.4 million). Income from small businesses as.sociated with the conservancies but not directly owned by them brought in another N$8 million (US$580 000).

Table 12.15 Conservancy-related income, 2006

Source of income	Value in N$	% of total conservancy income
Miscellaneous	34788	0.1
Premium hunting	43600	0.2
Veld products	39000	0.1
Thatching grass	2450481	9.1
Shoot and sell hunting	504883	1.9
Interest earned	161807	0.6
Craft sales	474343	1.8
Campsites and community-based tourism enterprises	3746481	14.0
Trophy meat distribution	870219	3.2
Game donation	860950	3.2
Use of own game	739629	2.8
Trophy hunting	6113923	22.8
Joint-venture tourism	10794668	40.2
Total	**26834772**	**100.0**

Source: WWF et al. 2007: 113

An important aspect of development has been the involvement of women in the employment benefits. Such jobs have included being game guards and natural resource monitors, as well as serving tourists in campgrounds and lodges.

Rising income from conservancies has made possible increasing investment in social development projects. This has made conservancies an increasingly important element in rural development.

Scaling-up resource management

Following the perceived success of community conservancies, the Namibian government has extended the concept to **community forests** (Figure 12.54). Establishing a community forest is similar to the process of forming a conservancy. This is a good example of the **scaling-up process** from one natural resource system to another. Based on the Forest Act of 2001, the project helps local communities to establish their own community forests, to manage and utilise them in a sustainable manner. Because many rural Namibians are poor, it is important that they have a greater say in how forest resources are managed and share the benefits of properly managed forest resources.

Forest fires and uncontrolled cutting have been two of the main problems facing forest-protection efforts in Namibia for some time. About 4 million hectares of forest and veld are burnt annually, mostly as a result of fires started deliberately to improve grazing and to clear hunting grounds.

The advent of community forests has led to improved forest resource management. It has also improved the livelihoods of local people based on the empowerment of local communities with forest use rights. Villagers in community forests derive an income by marketing forestry products such as timber and firewood, poles, wild fruits, devil's claw, thatching grass, tourism, honey from beekeeping, wildlife, woven baskets and other crafts.

Based in large part on the success of CBNRM in the conservancies, the Namibian government enacted legislation in 2001 allowing the formation of community forests – areas within the country's communal lands for which a community has obtained management rights over forest resources such as timber, firewood, wild fruits, thatch grass, honey, and even some wildlife (MET 2003). The establishment of the community forest program shows how the scaling-up process can reach across natural resource systems, affecting natural resource policy at the broadest level. Although the community forest program and the conservancy program are now administered separately by different ministries, some groups have expressed interest in merging the programs to allow a more integrated approach to managing natural resources at the community level (Tjaronda 2008).

Establishing a community forest is similar to the process of forming a conservancy. Communities must:

- Submit a formal application to the government;
- Elect a forest management committee from the community;
- Develop a constitution;
- Select, map, and demark a community forest area;
- Submit a forest management plan describing how the community will harvest forest resources sustainably and manage other activities such as grazing and farming within the forest area;
- Specify use rights and bylaws necessary to act on their management plan;
- Craft a plan to ensure the equitable distribution of revenues to all community members; and
- Obtain permission from the area's traditional authority (MET 2003).

As of April 2008, a total of 45 community forests had been formed (although only 13 were officially gazetted), encompassing 2.2 million ha and benefiting some 150,000 Namibians. In the north-eastern region alone, 16 registered forests have generated more than N$300,000 (US$38,000) since 2005 (The Namibian 2008; Tjaronda 2008).

Figure 12.54 Extending the conservancy concept – community forests in Namibia

Country Pilot Partnership for Integrated Sustainable Land Management

The Government of Namibia identified land degradation as a serious problem that demanded remedial intervention. Five government departments, together with international agencies, established a Country Pilot Partnership for Integrated Sustainable Land Management. The activities were funded through the Global Environment Facility (GEF) in partnership with the United Nations Development Programme (UNDP) as implementing lead agency. Other organisations including the European Union were involved.

The pilot project began in early 2008 and ran until late 2011. The project objective was to develop and pilot a range of coping mechanisms for reducing the vulnerability of farmers and pastoralists to climate change, including variability. It took place both within and outside communal conservancies. Its organisation was at least partly based on what Namibia has learned from the establishment of communal and forest conservancies.

Section 12.4 Activities

1 Why was the Community Conservancy Programme introduced?
2 How have employment opportunities expanded under the conservancy programme?
3 Comment on the importance of the Namibian Association of CBNRM Organisations to the success of the Communal Conservancy Programme.
4 Comment on the distribution of conservancy-related income shown in Table 12.15.
5 Describe and explain the extension of the conservancy concept to forests in Namibia.