Working with our environment: an introduction

Working with our environment: an introduction

OpenLearn | Free learning from The Open University

About this free course

This free course provides a sample of level 1 study in Environment & Development http://www.open.ac.uk/courses/find/environment-and-development

This version of the content may include video, images and interactive content that may not be optimised for your device.

You can experience this free course as it was originally designed on OpenLearn, the home of free learning from The Open University: http://www.open.edu/openlearn/nature-environment/the-environment/environmental-science/working-our-environment-introduction/content-section-0.

There you'll also be able to track your progress via your activity record, which you can use to demonstrate your learning.

The Open University, Walton Hall, Milton Keynes MK7 6AA

Head of Intellectual Property, The Open University

The Open University.

United Kingdom by Hobbs the Printers, Brunel Road, Totton, Hampshire.

Contents

Introduction

Global warming: are we responsible? Is our environmental impact damaging the planet? This free course examines the use of ozone depleting technology and the impact of fossil fuel use and explores how the development of technology can influence the direction of a society. From the Industrial Revolution to the present day find out how we have changed the planet.

This OpenLearn course provides a sample of level 1 study in Environment & Development

Learning Outcomes

After studying this course, you should be able to:

- demonstrate an awareness of different ways in which our use of technology can affect the environment
- demonstrate a set of skills in reading and interpreting texts and diagrams containing some technical descriptions.

1 Introductory advice

There are two ways to approach this course. The first is the more natural one: to read it straight through to get a general feel for its style and content, and to see whether you are going to find the course and the issues it raises interesting; in short, to get an overview. There is nothing wrong with this at all.

You will find as you read through it, though, that the course covers a wide range of topics. In part this is because the authors takes a broad view of 'Technology'. We see it as the application of science and other knowledge to practical tasks by people working in organisations and using machines. In other words we are interested in the *interactions* between people, their organisations, and what they produce and consume. The other, related, reason is that in studying environmental issues we need to draw on a wide range of academic disciplines from biology and the earth sciences through to management and the social sciences.

(Tip: Whenever the key concepts 'environment', 'technology' and 'sustainability' are discussed in the text, keep a record of where this happens and make your own notes on how each term is described or defined.)

As you read through the text you will come across different technical ideas and terms. While you may well be familiar with some of the areas, it is likely that others will be new to you. In this case, taking the time to do a bit of research to check to your own satisfaction that you are following the argument and evidence being presented should improve your confidence in handling the material. But it is not just the technical material you should look out for. Inevitably in such an overview I have made many assumptions about you, the reader, about the views we might hold in common, and have also introduced my own values and prejudices. In places I try to make this subjectivity clear, and ask you to consider a different viewpoint; your own or another's, for example, but only to a limited extent. So be wary: don't just accept what you are told, look for arguments and evidence to support each statement as you read through the course.

The second approach, then, is to be an active and engaged reader and to take responsibility for your own learning as you read through the course. This is more difficult, it takes longer, but is ultimately much more rewarding. The purpose of the advice in the last section of this study guide is to explain how the course material can be used to help you learn as you read, and give you some pointers to do this. One of the best ways to help you in this task is to make your own notes as you go along.

What you have to do

Studying this course should take you around 11 hours. Each section builds on some of the ideas preceding it, so I recommend you read it in order.

First, the course contains quite a few technical terms and concepts. Each time a new technical concept is introduced it will appear in **bold**. This means it is defined or described in the *Glossary*. You may or may not be familiar with the term, but you are recommended to refer to the entry in the *Glossary* because we may use the term differently from you. You'll find the *Glossary* by clicking on screen number 25 at the top or bottom of this pane. I suggest you keep it open in a separate browser window throughout your study.

To help you manage your studies, and if you plan to study further, you might like to think about obtaining a copy of *The Sciences Good Study Guide* by A. Northedge et al., published by Open University Worldwide. Where particular skills, such as reading, note taking and using diagrams may be needed to help your study, you can read the appropriate section. How often you will need to do this will, of course, depend on your existing skills.

Finally the course contains some Exercises and Self-assessment Questions (SAQs) which I recommend you attempt. Their purpose is to help you engage with the course, and to consolidate your understanding of it. It is tempting just to look at the answers, but if you make the effort to answer them yourself, you are far more likely to appreciate and remember the points being made. Good luck with your studies!

2 The world we live in

2.1 Environment and technology

A central concern of environmental studies is the relationship between technology and our environment: how people use technology to transform materials into forms which can meet our needs and wants. In the process of doing this we inevitably change the environment which provides these materials but which also supports all life.

A few moments ago I went to my fridge and took some milk out to add to a cup of coffee. I used this common example of a modern domestic appliance without a second thought, as I have done on countless occasions before. For me and for many others a fridge provides a convenient and hopefully safe store for milk and other foodstuffs. Surely this adds to our general well-being, but are we at the same time harming our environment?

I won't attempt to answer this question directly here; instead I will introduce you to some ideas and case studies that present the issue from a variety of different standpoints. I hope that this approach will give you a broad perspective which you can use to explore and assess such issues, as well as giving you a taste of environment-related studies. But just before we start I had better try to clarify what I mean by the environment. In everyday language there are many environments – the economic environment, the political environment, for example – as well as the 'natural environment'. What we mean by these usages is the context in which we live and work, which both shapes and influences us and on which we, in turn, have an effect. They are all suitable topics for study, but this course is mainly concerned with what is often termed the natural environment: the physical and biological world which we and all living things inhabit, interact in and share. The question is, what exactly do we mean by natural?

2.2 We are part of nature

Take a few minutes to look around at your surroundings before you read on. What do you see? Obviously this depends on where you are at the moment: at home, at work, or perhaps travelling in between, or maybe you have the misfortune to be laid up in hospital. Possibly like me you are at home. I am fortunate to have a study where I do much of my writing and you won't be surprised to hear that I'm looking at a computer screen at the moment. What else can I see? Books and bookshelves, furniture of various sorts, pictures, a camera, some clothes, then a carpet on the floor, electrical leads, plugs and a socket, lighting, a radio, a radiator, walls and ceiling, a door, and a window overlooking a small and somewhat untidy garden. I don't know what *you* can see, but wherever you are, it is likely that what we are both looking at has several important features in common. It is a scene made almost entirely of manufactured materials, which may have come from almost anywhere in the world. I can see products made from wood, cotton, paper, metal, cardboard, glass, and a variety of **polymers**, while hidden behind my wallpaper are plaster, bricks and mortar. In most cases I can only guess where all these materials might have come from.

This material world we inhabit is one we humans have largely designed and manufactured, and is supported by an amazing infrastructure of transport, communication and many other services that we take for granted. Without them, for example, you wouldn't be reading this page or studying this OpenLearn course. The technological basis of our society has undergone major transformations in the last two centuries and whether you regard such changes as 'progress' or not, today you would probably find it hard to manage without most of them. Certainly, if I were honest, I would have to admit that I would be reluctant to lose most of my creature comforts, ranging from central heating to my CD player.

But, you might argue, I have only really described my home, which has been designed and built, and is surrounded by a built urban environment. You could point out that the countryside and open spaces are quite different, and you might be fortunate enough to be reading this in such surroundings. Even in towns 'nature' is hard to avoid whether in the form of the flowers and vegetables (and weeds) in my garden, the cats which trample over them, or even the pot plant standing on the window-sill. And what of ourselves, aren't we part of nature as well? To all this, I would have to agree, yes, we are certainly part of nature. Figure 1 illustrates this relationship in a simple way.

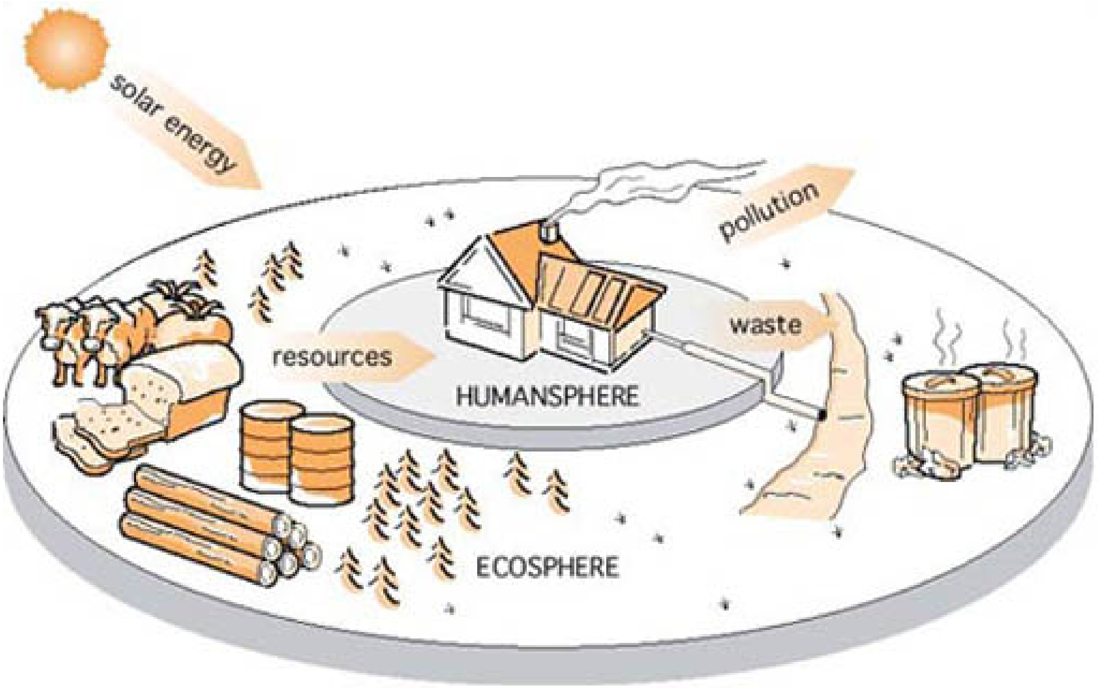

Figure 1 We are part of nature. Nature supplies material requirements for life, absorbs our wastes, and provides life-support services such as climate stabilisation, all of which make Earth hospitable for people.

One of the ideas that will be developed in this *Introduction* is that we can't escape from nature's laws, but *our* impact and influence on our environment spreads far beyond our immediate surroundings. The landscapes you can see in the British Isles, from the close hedge-rowed pastures still found in western parts of the country, the grain fields of the East, to the heather and bracken covered uplands of northern Britain, have all been modified by human occupation and agriculture. A similar pattern prevails through much of Europe where the human influence can be quite marked, as in the agricultural land recovered from the sea in the Netherlands, and the ancient vineyards and olive groves of the south. Even in high mountain regions, such as the Alps, away from the ski developments, local populations have attempted to control and channel the naturally destructive forces that mould the landscape, through river management, including hydroelectric schemes, and avalanche control.

There are very few landscapes which we have not altered. Many of these are actively managed by us for our own use, for agriculture or leisure, for example, and most of the rest are also affected by our activities whether we mean to or not. Even the atmosphere and the oceans have been modified by us in ways that we are only beginning to understand, and these, in turn, affect the flows of energy and materials to all **ecosystems**. It is, then, difficult to make a clear distinction between a 'managed environment' and a 'natural ecosystem', although we can all understand the difference in principle between planned management and inadvertent change.

Not only are we part of nature, but, as Figure 1 suggests, we exert an increasingly dominant influence on our planet. Our ability to make use of its resources, whether animate or inanimate, for our own ends is the basis of our material affluence, bringing benefits to many, though by no means to all. We cannot assume, however, that the goods and services we take from our natural surroundings are either limitless or free. In particular, if we disturb the environment beyond its natural abilities to sustain itself or respond to change, there may be adverse and unexpected consequences. Now, this last sentence can be interpreted in many different ways from the alarmist to the complacent. I would place myself somewhere in between these extremes. I believe we face many difficult environmental issues, some more serious than others, and that we are likely to discover many more in the future. I also believe that science and technology, wisely used, can help us solve, or at least mitigate, many of them. But every time we intervene to manage or control an environmental problem we have to take responsibility for the consequences. Increasingly we are becoming the managers or **stewards** of our environment – whether we like it or not.

Your opinions may well differ from those expressed in the last paragraph. Since you have chosen to study this course about the environment, I would not be surprised if you already have quite strong views about some of the environmental issues we face.

Exercise 1

What are the most pressing environmental issues that concern you at the moment? Spend a few minutes thinking and making notes on, say, *four environmental issues* before reading the discussion below.

The first point to emphasise is that there are no right or wrong answers to a question such as this. The issues that you have identified as important will depend on your circumstances, your priorities and your **values**. For example, you may be interested in several global environmental issues; alternatively you may be concerned about a particular local problem that affects you directly.

Here are a few issues you might have considered, but please note that my list makes no claim to be comprehensive, and, by the time you read this, new environmental topics may have become topical causes for concern and discussion. From a range of possible *global* environmental issues I'll mention just a few: **global climate change;** the continuing threat to the **ozone layer;** loss of natural **habitats**, e.g. tropical forests; loss of **biodiversity**, including threats to individual **species**, from insects to whales; and the depletion of vital natural resources such as oil and gas. At the other end of the scale the issues which may concern you are likely to reflect your local situation and these may vary widely. If you live in a city, noise, air pollution and litter may be on your list; in the countryside it may be protection of open spaces, or access to them, or perhaps worries about certain farming practices. Other important issues include access to sufficient clean water, and to safe, healthy food and the related matters of how these resources are distributed, which could be thought of as either local or global problems depending on your perspective. You may be thinking about solutions as well, from energy saving and recycling, to participating in planning decisions about new developments. For comparison I've included Figure 2 which shows part of a report by the Electrolux Group on public reactions to environmental issues. The problems identified are arranged according to geographical and time scales. You may well find you have some concerns in common!

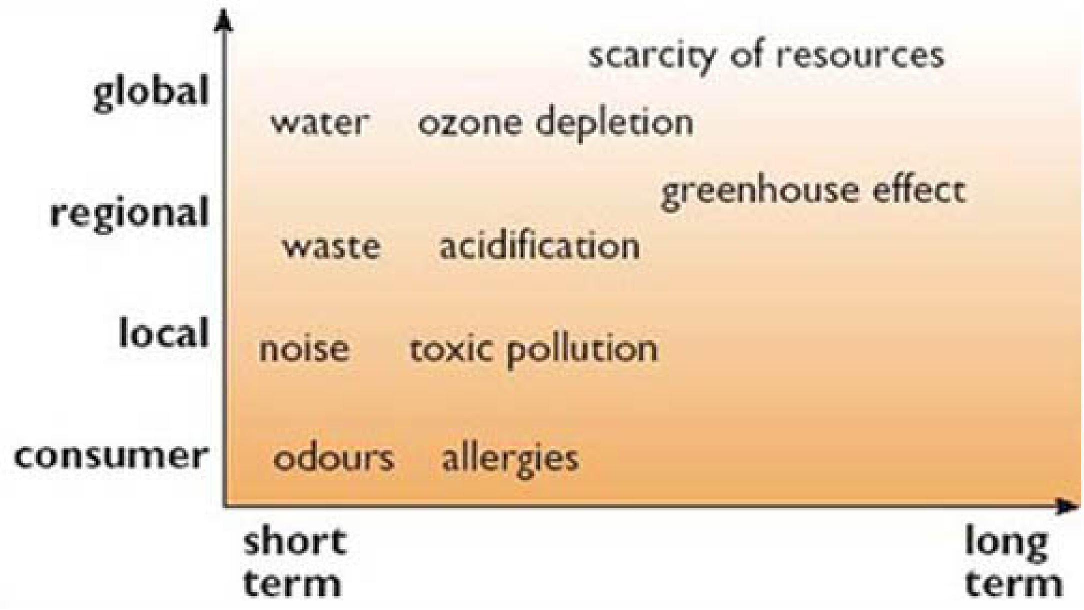

Figure 2 Public reactions to environmental issues.

To end this section, I'd like to emphasise a point made in the previous discussion; that people in different situations, in inner cities, in the countryside, in affluent or developing countries, are likely to have quite different priorities. When solutions or agreements are being discussed which may affect widely differing groups it is only common sense to find out and take into account their different perspectives.

2.3 The Industrial Revolution and its environmental impacts

The environmental issues you have identified in your answer to the first exercise are likely to be complex and difficult to unravel, yet alone resolve. Rather than attempt that at this stage I'd like to start this section with another question. *Where does our material prosperity come from?* To which one short answer would be 'The **Industrial Revolution**'. In the space of less than 100 years between the eighteenth and nineteenth centuries, first Britain, then several other countries completely transformed the nature of their economies. By looking briefly at the development of the industrial economy which underpins our present societies, we may hope to gain some insights into topical concerns.

You can gain some of these insights through reading Tim Jackson's chapter 'Material transitions: the birth of the industrial economy' in *Material Concerns: pollution, profit and quality of life*. In this chapter he describes the massive increase in energy use, obtained by burning fossil fuels, which powered the development of new industries, transport and a massive throughput of material, and also allowed a large increase in the UK population.

These impressive increases in material flows, enabled by our control of powerful sources of energy, then transformed by new technologies into machines and goods, were the basis of much of the material wealth of a newly industrialised Britain. The industrial base was also the guarantor of its military prowess which allowed it access to the resources of a growing empire, but that is another story. Another effect of the Industrial Revolution, as Jackson points out, was the mass migration of populations from the countryside to the fast growing towns and cities where the factories and work were to be found.

> 'And what cities! … smoke hung over them and filth impregnated them, the elementary public services – water supply, sanitation, street-cleaning, open spaces, and so on – could not keep pace with the mass migration of men into the cities, thus producing, especially after 1830, epidemics of cholera, typhoid and an appalling constant toll of the two great groups of nineteenth century urban killers – air pollution and water pollution or respiratory and intestinal disease.'
>
> (Hobsbawm, 1969, p. 86)

Air and water pollution came, for example, from coal burning, as well as most stages in the production of metals and basic chemicals. In the absence of suitable sanitation and refuse collection, waste from domestic sources caused additional problems. The impact on the health of urban populations from water-borne diseases like cholera and typhoid, from air pollution, and occupational exposure to hazardous materials was often devastating, and particularly affected working families housed close to the industrial sources. The levels of pollutants that occurred regularly then would lead to prompt action now, at least in more prosperous countries and localities. Yet in spite of the harm to populations in the vicinity, the impacts of pollution generally remained localised, and by today's standards only a limited range of chemical compounds and materials was used by industry. Often the simple expedient of dispersing the pollutants more widely, by using a high chimney, for example, seemed sufficient to solve the problem.

2.4 Changing environmental attitudes

So, from the start of the Industrial Revolution, people have been aware that the development of an industrial economy brings problems as well as benefits. But the benefits, in terms of productive capability, mobility, convenience, cheap consumer goods, and profits, were usually felt to outweigh the disadvantages, particularly by those in positions of power. Many of the accompanying negative factors, such as poverty and unemployment, or the creation of more destructive machines of war, if they were regarded as problems, were laid at the door of society rather than technology. The adverse effects on the environment were usually seen to be localised and short-lived, and accepted as an inevitable cost of progress, to be dealt with only when there was a clear and immediate threat to life and livelihoods. People had more pressing priorities than concern about the environment, particularly at a time when its ability to supply goods and services, and its capacity for absorbing wastes and pollution seemed limitless.

It is probably true to say that the predominant view in industrialised countries, persisting well into the twentieth century, was that the transformations being wrought by science and technology were being used wholly in the service of progress (after all a combination of medical advances and good plumbing was steadily conquering many of the most dreaded infectious diseases). Nature, while occasionally needing our protection in badly polluted localities, was felt to be robust and bountiful enough to be managed, tamed and exploited as we wished. This belief probably reached its peak in the 1950s and early 1960s, and appeared to be amply confirmed by the development of nuclear power, which promised to provide 'virtually free' electricity for all: the ultimate technological triumph.

This view was very shortly to be challenged. Several events conspired in the 1960s and 1970s to lead some to realise that our environment was not infinitely large or rich, that there were limits to the resources we could take from it and the rate at which the environment could absorb the waste generated by economic and industrial growth. Rachel Carson in her book, *Silent Spring*, published in 1962 (Carson, 1962), was one of the first to bring into the public domain concerns about the widespread use in the USA of **DDT**, other **organochlorine** compounds and **organophosphates** as pesticides. She outlined their **toxicity** and persistence and documented their accumulation in **food chains** and damaging effect on wildlife, particularly birds and fish. She also discussed several issues that remain topical: the possible effects of these chemicals on people, and the development of resistance to them by the target insects, including malarial mosquitoes. In addition, she gave a full account of biological control as a practical alternative to the chemical approach. Her views were not immediately embraced by the establishment. Indeed many vigorously contested them, including scientists and workers in industry and agriculture, but the debate had been opened up and has continued ever since.

It is perhaps not surprising that new risks accompanied the rapid expansion in the variety of new materials and chemicals used in industry and agriculture to serve the burgeoning consumer society. Globally, the chemicals industry is the largest source of toxic emissions, with approximately 40 per cent* of emissions, and has also been responsible for fatalities in some major pollution events, though fortunately these are not frequent occurrences. Tim Jackson describes the proliferation of new chemicals, as this short excerpt illustrates:

> “The chemicals industry in the United States, for example, has expanded more than tenfold in the last forty years. Approaching 100,000 industrial chemicals are now in commercial use world-wide, and this figure is increasing at the rate of between 500 and 1,000 new chemicals each year. This increase has been driven in part by the availability of petroleum-derived by-products of an expanding oil industry, and in part by the increased role for new and complex chemicals in new and expanding technological contexts: agriculture, metal purification and metal plating, electronics [and computing], textiles and the food industry.”
>
> (Jackson, 1996, p. 29)

Today, in many countries, chemicals that are *known* to be toxic, or hazardous in other ways, are strictly controlled and in some cases banned for industrial purposes. The key word here is 'known'. Knowledge or proof of harm from a particular substance is not always easy to come by, even though the potential hazards can often be anticipated from its intended use and action, and from its chemical formula.

At the start of the *Introduction* I speculated whether my use of a refrigerator might be damaging the environment. I will now follow up this point through three Case Studies which explore different aspects of the use and environmental impacts of refrigerators and refrigeration. The first explores the relationship between refrigerators and an unusual set of chemicals, which were given the proprietary name of **freons**. Freons appeared to be totally safe and inert, and had some useful physical properties that proved to be invaluable to the refrigeration industry. After more than forty years of apparently trouble-free use, the discovery that they posed a major threat to human and environmental health was thus all the more shocking. Today they are better known by the abbreviation, CFCs, or by their full name, **chlorofluorocarbons**.

3 Case study 1: Refrigerators and the ozone layer

3.1 Refrigeration and chlorofluorocarbons

A domestic refrigerator consists essentially of two elements. First, it has a well-insulated box that minimises the flow of **heat** energy from the warmer outside environment to the cold space inside. Second, it has a motor to circulate a cooling liquid or refrigerant which extracts heat from the cold space and carries it to the outside, where it is released, usually through a radiator at the back. Most refrigerators make use of the principle that when liquids vaporise – that is, change from liquid to gas – they take heat from their surroundings; when the gases condense back to liquid they return heat to the surroundings. As the fluid refrigerant is pumped around in closed circulation, the trick is to expand and vaporise it while it is inside the cold space, and to compress and condense it again once it has moved outside the cooled region.

Early refrigerators used a variety of potentially unpleasant and dangerous chemicals for refrigerants, for example, ammonia and **sulphur dioxide**. So there was a lot of interest from the industry when, in 1928, DuPont discovered an entirely new range of chemicals known as chlorofluorocarbons, or CFCs, which were neither toxic nor flammable, seemed practically non-reactive, and had suitable thermal properties. They were introduced as refrigerants in the 1930s, relatively soon after their discovery. Later, in the 1960s, CFCs found another use as blowing agents for foam insulation, to replace the less effective glass fibre insulation then used in refrigerator cabinets.

Alas, we now know that these chemicals have the potential to damage the ozone layer in the **stratosphere**. The ozone layer in the upper atmosphere, high above our weather systems, absorbs **ultraviolet (UV) radiation** from the sun and prevents it from reaching the surface of the planet, where it can be harmful to life. Sherwood Rowland was one of the two scientists awarded the Nobel Prize for the discovery, in the early 1970s, of the potential dangers of CFCs. One night, while he was working on the problem, his wife asked him how his work was going. Rowland replied despondently, 'Very, very well. But it looks like the end of the world' (Ochert, 1999).

This discovery in the 1970s gave a major jolt to the science establishment; after all what possible threat could non-toxic, non-flammable, non-reactive chemicals pose? But it is precisely because CFCs are so stable that they last a long time in the atmosphere and are eventually able to reach the stratosphere where they react with ultraviolet radiation to release chlorine **atoms**. In certain circumstances, for example, over the Antarctic during winter and spring.

3.2 The agreement to protect the ozone layer

After a decade of controversy about the possible effects of CFCs, in 1985 British scientists discovered over the Antarctic a quite unexpected 'hole' in the ozone layer which was the size of the USA. This helped to galvanise the international community into action (though some who took part in the negotiations claim it played little part). By 1987 the first international agreement to control substances damaging to the ozone layer, the **Montreal Protocol**, was established. Interestingly the agreement was reached before there was evidence to link the ozone hole with CFCs and without any definitive examples of damage to humans or ecosystems.

The agreement has been rightly hailed as ground-breaking: by weighing current political and economic pressures against uncertain long-term hazards it was the first successful international agreement to incorporate the '**precautionary principle**'. Later events have shown the wisdom of this approach. Each subsequent review of the agreement has tightened up the control of substances contributing to **ozone depletion**, as the scientific evidence of their effects became clearer, and frequently more alarming.

In industrialised countries, the production of CFCs and their use in new appliances has been banned since 1996, apart from critical uses, as in asthma inhalers, where no safe replacement has been found. This has resulted in global CFC production (weighted for ozone depletion impact) dropping by nearly 90 per cent from its peak in 1988 to 2000 (Figure 3).

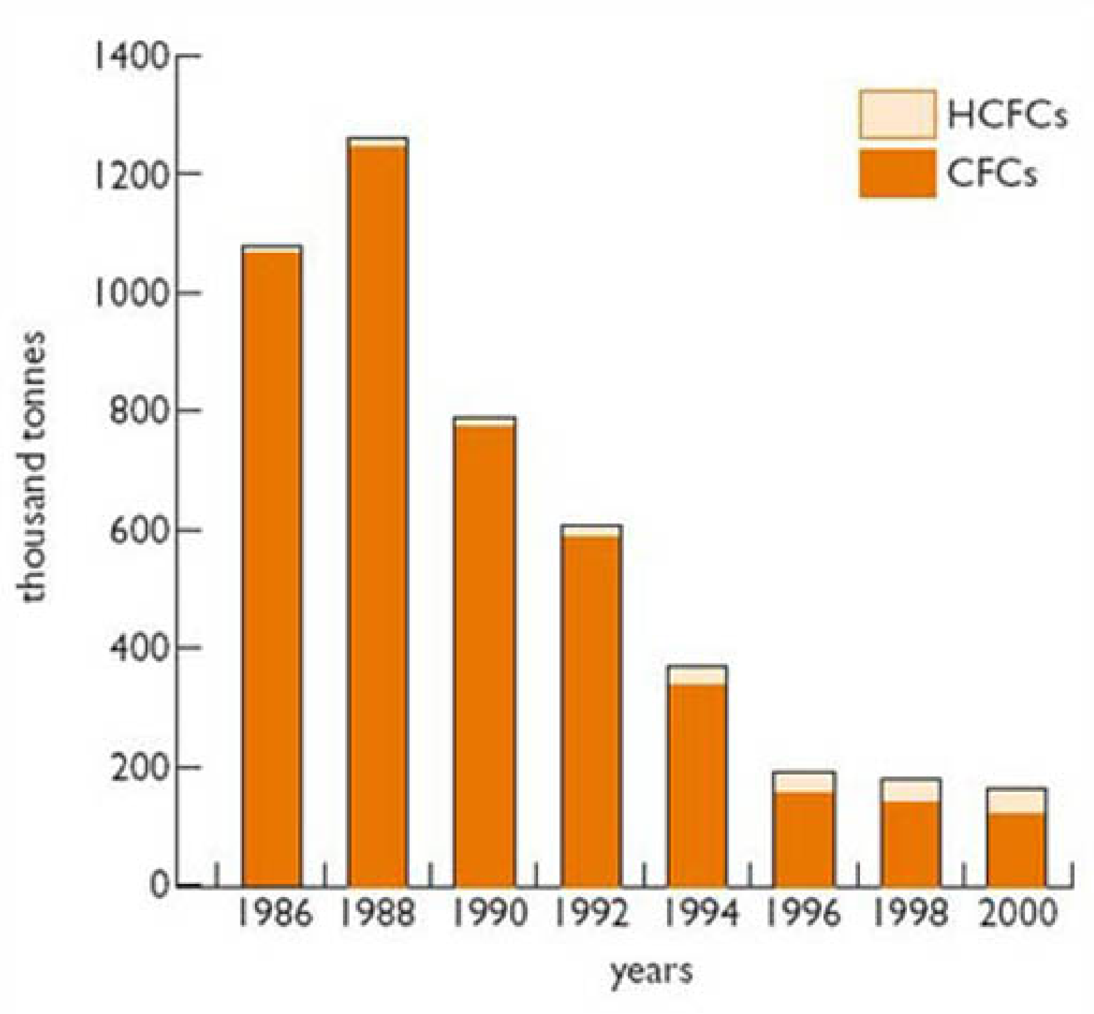

Figure 3 CFC production (weighted for ozone-depleting impact) continues to plummet. 'Data source: UNEP/Ozone Secretariat. 2003, report of the Technical and Economic Assessment Panel.'

Levels of CFCs and other ozone-depleting chemicals peaked in 1994 in the lower atmosphere and by 2000 in the stratosphere, but will remain dangerously high for many decades because of their persistence. That is not quite the end of the story. Industrialising countries such as China, Brazil and India now account for almost all remaining CFC production (Figure 3). This group were exempted from the 1996 ban but agreed to freeze production in 1999 and reduce it incrementally to zero between 2005 and 2010. There remain problems with the safe disposal of CFCs in current use and illegal smuggling of chemicals from countries still in production. But areas of non-compliance with the agreement are likely to be of less practical significance than one of its compromises. It was only accepted by some manufacturers on condition they be allowed to use 'transitional' compounds for some purposes, to give them time to find and develop suitable long-term substitutes. The main family of transitional compounds (which are known still to damage to the environment) are called **HCFCs**, but for this discussion I will also include another group known as **HFCs**. Both groups are described in Box 1, which also lists some of their properties which can affect the environment.

SAQ 1

You are not expected to be familiar with the chemistry of CFCs and their substitutes, but Box 1 should help you to identify their potential for environmental damage. Read through it now then answer the following question.

What possible environmental problems could arise from using the two transitional compounds HFC 134a and HCFC141 b?

Answer

Although you have not been given any specific information about HCFC141 b and HFC 134a, you can expect each to have the properties described for the chemical family it belongs to.

As can be seen in Figure 3, which compares the ozone-depleting potential of HCFCs to CFCs, HCFCs including HCFC 141 b still have the potential to damage the ozone layer, though much less so than most CFCs. (In fact, molecule for molecule, its potential is about 10 per cent that of CFCs and this makes it the most damaging of the commonly used HCFCs.) HCFC 141b is also a powerful greenhouse gas. Its release in significant quantities could contribute both to ozone loss and global climate change.

HFC 134a does not have the potential to harm to the ozone layer, but is a very powerful greenhouse gas. Its release in significant quantities could contribute to global climate change.

The refrigeration industry is a major user of both HFCs and HCFCs. Two compounds in particular have been favoured by them: HFC134a, as a refrigerant, and HCFC141b, as a foam blowing agent used in making insulation. Manufacturers have emphasised the desirable side of their properties, in particular their safety and effectiveness compared with alternatives, and, according to some pressure groups, have been reluctant to consider any other options. They moved quickly into production of these substitutes, which grew significantly in the late 1980s and 1990s, as illustrated in Figure 4. HCFC production peaked in the late 1990s and is now declining, while HFC continues its rapid rise in output, reaching 160 000 tonnes in 2002. The decline in CFCs in the 1990s (Figure 3), used mostly for refrigeration and foam blowing, has been mirrored by a corresponding rise in its substitutes.

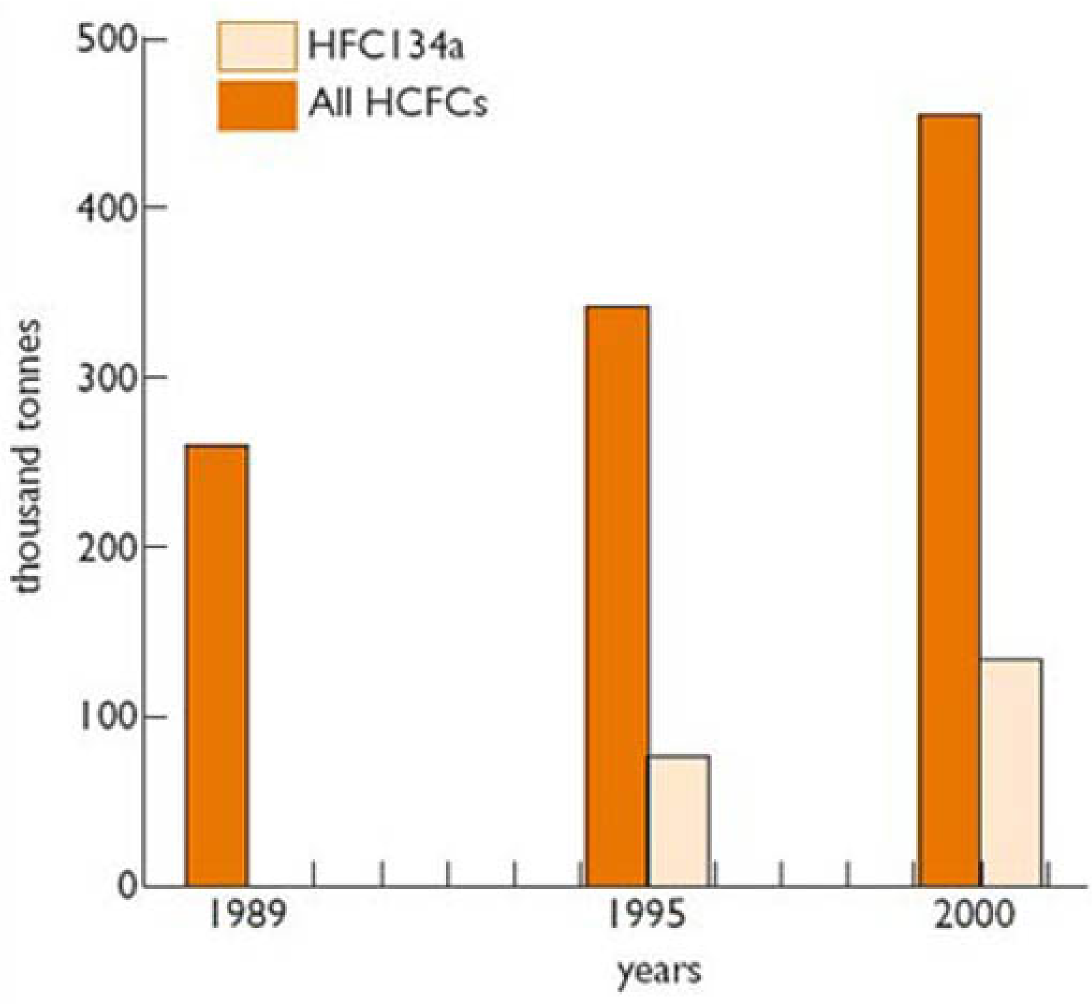

Figure 4 UK supply of CFCs and HCFCs in primary areas of application 1989–2000. 'Data source: UNEP/Ozone Secretariat. 2003, report of the Technical and Economic Assessment Panel.'

Box 1: The environmental effects of CFCs and their substitutes

CFCs

CFCs or chlorofluorocarbons (compounds of chlorine, fluorine and carbon): These are highly stable molecules, with typical lifetimes in the atmosphere of between fifty and a hundred years. The most common compounds contain two or three chlorine atoms.

CFC substitutes

The two main families of chemical compounds developed as substitutes for CFCs, HCFCs and HFCs, are interim or transitional compounds, to be used for a limited time until more environmentally benign alternatives can be found and developed. The two properties of CFCs that give them the potential to damage the ozone layer are their stability and the number of chlorine atoms they contain. In the substitute compounds some or all of the chlorine atoms are replaced by hydrogen atoms. This has the effect both of reducing the length of time they persist in the atmosphere, so less of the compound eventually reaches the stratosphere, and, once it does, of reducing the amount of chlorine available for release to threaten the ozone layer.

HCFCs or hydrochlorofluorocarbons (compounds of hydrogen, chlorine, fluorine and carbon): In this family one or more of the chlorine atoms has been replaced by hydrogen atoms. This produces a less stable molecule that has a shorter lifetime in the atmosphere, typically about twenty years. Their potential for damage to the ozone layer is between a tenth to a twentieth that of CFCs.

HFCs or hydrofluorocarbons (compounds of hydrogen, fluorine and carbon): All the chlorine is replaced by hydrogen and thus HFCs are not damaging to ozone. They have similar lifetimes to those of HCFCs.

All of these three families of compounds, however, are also very potent **greenhouse gases**. Typically, measured over a lifetime of 100 years, each molecule of HCFC or HFC has the same effect as approximately *one thousand* molecules of **carbon dioxide**, and will thus contribute strongly to global climate change.

Some **hydrocarbons** (compounds only of hydrogen and carbon), for example, propane and isobutane, are now increasingly being used in refrigeration as a 'greener' alternative to both the CFCs and their transitional replacements. These, too, are greenhouse gases, with each molecule having approximately *ten* times the effect of a molecule of carbon dioxide. While this is still significant, it is considerably less than the effect of HCFCs or HFCs.

Source: Blackmore and Reddish (1996).

3.3 Greenfreeze: the Greens fight back

Some campaigners were not convinced by the arguments of refrigerator manufacturers and suppliers (who also happened to own some patents for HCFCs and HFCs) that the only solution, in the short to medium term, was to use the transitional compounds. They tried to demonstrate that there were practical alternatives. A group of scientists working with Greenpeace International designed a domestic refrigerator based on the use of hydrocarbons, using a mix of propane and isobutane for the refrigerant, and cyclopentane as the blowing agent for foam insulation. They linked up with an East German company, Foron, to produce the first 'Greenfreeze' model and quickly established the principle of HCFC- and HFC-free refrigerators. The arguments from manufacturers about cost, safety, (hydrocarbons are flammable), and efficiency of insulation have mostly been answered now, and in 2003 Greenpeace estimated that 120 million domestic fridges of this type were in use worldwide. The industrialised countries are committed to phase out HCFCs between 2004 and 2020, but not HFCs. HFCs are powerful greenhouse gases (SAQ 1), but do not deplete ozone and are not covered by the Montreal agreement. The European Council has agreed to cut HFCs and the majority of European manufacturers have now turned to hydrocarbons, but not yet their US counterparts.

Until the discovery of the ozone hole few realised the extent to which the modern industrial economy was capable of posing global threats to the environment, especially with what were considered to be the most innocuous materials.

However, I think that the conclusions to be drawn from this first case study are more positive than negative. The response of the international community, though criticised at the time, almost certainly avoided a major catastrophe and its success surprised many of the original participants in the negotiations. Indeed, the international processes and agreements reached over ozone now serve as a model for solving other global environmental problems which require international agreement. And although the threats to the ozone layer and the discussions over implementation of the Montreal Protocol are by no means over, the Greenfreeze episode emphasises that while technologies can be the source of environmental problems, used imaginatively they can also be the basis for environmentally acceptable solutions.

Figure 5 The 'Greenfreeze' refrigerator, developed and made in Germany, with support from Greenpeace, uses propane/butane mixture as a refrigerant and expanded polystyrene blown with pentane for insulation. These gases do not deplete the ozone layer.

4 Case study 2: Refrigerators and climate change

4.1 Domestic appliances and fossil fuels

For this second case study I shall look specifically at the energy use of domestic 'cold appliances', that is freezers and refrigerators, and discuss whether efficiency measures can play a significant role in reducing their energy consumption. The reason for this is quite simple. For many years there has been well-documented evidence of the damage to the environment and cost to human life associated with the extraction, transport and consumption of fossil fuels such as coal and oil, from smogs to acid rain, mining fatalities to oil spills, and from time to time there have been concerns about the security of fuel supplies: would they run out? or would they fall into the hands of unstable regimes? Over the last 20 years another issue has gained prominence: the likelihood that the carbon dioxide emitted when we burn fossil fuels is now reaching the atmosphere in such large quantities that it is changing our very climate.

To set the scene I'll start with an account from several decades ago, when domestic refrigerator design in the United States could apparently afford to ignore such considerations.

4.2 The US experience: wasteful innovation?

In the 1950s and 1960s many industrialised countries experienced a prolonged period of economic expansion which, together with the rise of consumerism, created an increased demand for domestic appliances. With ready access to cheap supplies of fuel, there was little or no incentive for manufacturers or consumers to worry about energy conservation. Nowhere was this more evident than in the US, as the following extract from the influential book *Factor Four* of the design developments in domestic refrigeration illustrates (von Weisäcker et al., 1997, p. 33).

> 'The main failing in most refrigerators is their insulation. From about 1950 to 1975, as electricity became cheaper, refrigerator makers kept making the insulation thinner so they could make the inside of the refrigerator bigger without making the outside bigger… They also used very inefficient compressors, often mounted *underneath* so the heat would rise into the food compartment and have to be removed all over again… The door wasn't well sealed against air leaks, and when it was open to expose the open shelves, all the cold air would fall out. The thin insulation caused the outer surface of the box to 'sweat' with condensation in humid weather, so the manufacturers installed electric heaters to dry it out; until recent years these couldn't even be turned off in dry sites or seasons. The anti-sweat heaters teamed with the thin insulation to help the extra heat get back inside faster. Inefficient fans were added to distribute the cooling, substituting for good design in the first place, and to make sure the food got dried out as well as cooled. To reduce frosting

inside, electric heaters were put there too, along with inefficient lights, just to make sure the cooling system had plenty to do.'

The authors make the point forcefully (and with many more examples than this selection shows). There is no doubt that domestic refrigerators in the US at the time were not energy efficient, indeed each 'improvement' that was added seemed to create extra problems and to require extra energy to solve it again. Some of the problems that the designers were attempting to deal with, avoiding 'frost' for example, are not trivial, but only access to an apparently endless supply of cheap energy could explain the design extravagances that resulted.

In 1972 the average model sold in the US consumed 3.36kWh (**kilowatt-hour**, one of the standard units of electricity) of electricity per year, for each litre of cold space. The following year the 'oil shock' occurred and changed attitudes to energy use and conservation dramatically. State and federal governments soon began to introduce successively tighter **energy standards**. By 1998 major US manufacturers had agreed to work to a standard 0.86 kWh of electricity per litre of cold space – close to one quarter of the average value of 25 years earlier. It does not follow, though, that average electricity consumption in the US by refrigerators and freezers has fallen to a quarter of the 1972 figure. One reason is that the average replacement time for these appliances is about 15 years, so there is a considerable delay between the introduction of standards for new models and achieving their potential to reduce consumption. So, even in the late 1980s, a sixth of all US household electricity was still being consumed by refrigerators or combination refrigerator-freezers. (Which, as the authors of *Factor Four* point out, is equivalent to the output of about 30 Chernobyl-sized power stations.)

4.3 The UK experience: competing trends

But one striking example does not make an argument. To try to get a fuller and possibly fairer picture of energy use by domestic refrigerators I'd like also to look at the UK experience over the past few decades.

To start with it helps to have a feel for which parts of the UK economy use the most energy. The UK Department of Trade and Industry (DTI, 1998), identifies four main economic sectors: domestic (households), industry, services and transport.

In 2003 the domestic sector (households) accounted for 31 per cent of all energy consumption in the UK, and since 1970 energy use in this sector rose by a third (DTI, 2004). Energy consumption by households, then, is both significant and rising, but it is worth noting that energy use *per* household has changed little during this period; this growth in demand is almost entirely accounted for by an increase in the number of households in the UK.

Looking within households, the two major users of energy are space and water heating, which in 2002 accounted for 85 per cent of all consumption. Lighting and domestic appliances, including refrigerators and freezers accounted for much of the remaining energy use, with 13 per cent or one-eighth of the total. Significantly, energy use by the groups of appliances has more than doubled since 1970. (The figure of 13 per cent above refers to the energy *delivered* to households through electicity. In terms of primary energy, mostly the fossil fuels needed to produce the electricity, appliances consume more like a quarter of all household energy.)

In contrast to space and water heating, which are now usually provided in the form of central heating, with gas as the major source of energy, most domestic appliances make use of electricity. Figure 6 shows *electricity* consumption in households for different groups of appliances during the period 1970 to 2002. The broad categories of appliance we are particularly interested in – refrigerators, fridge-freezers and freezers – are here called 'cold appliances'.

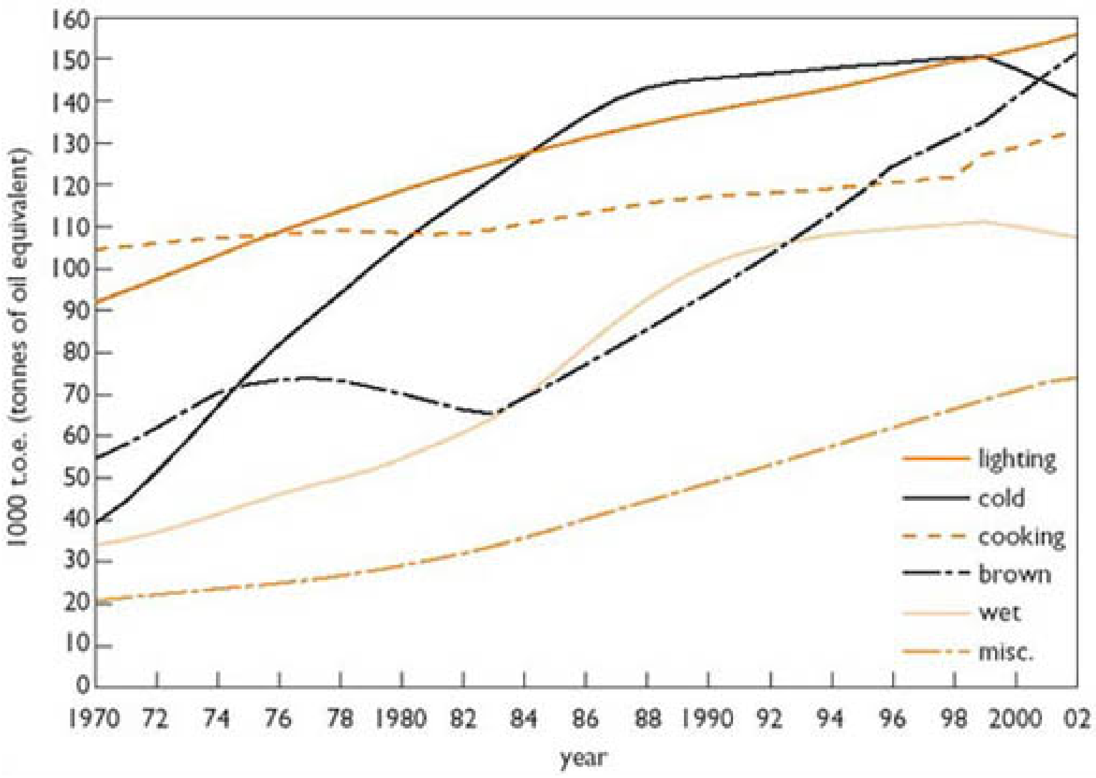

Figure 6 Electricity consumption by household domestic appliance by broad type, 1970–2002 (DTI, 2004)

Exercise 2

There are two features of the graphs I would like to draw to your attention. Look at Figure 6 now, and make a note of:

1. the two appliance groups which in 1999 used most electricity, and
2. the two groups which have accounted for most of the increase in electricity consumption between 1970 and 2002.

1. The two major uses of electricity in 1999 were the cold and lighting groups though since 1999 electricity use by cold appliances has started to decline.
2. The two categories of appliance that have increased electricity consumption the most are the cold and brown appliance groups. If you disagree check that you were looking for the two curves which showed the greatest rise between 1970 and 2002 (Brown goods are entertainment products including TV and audio products, VCRs and DVDs, but not computers. The unlikely term comes from the wood-coloured plastic cases of early products.) Over the period, electricity use for brown goods has risen threefold and by three and a half times for cold appliances.

What are the reasons behind the rise? Does it mean, for example, that the UK has not benefited from the improvements in energy efficiency seen in the US? In fact, the gains in energy efficiency noted for the US have also been observed in the UK, if on a less dramatic scale, for each category of cold appliance, such as refrigerator and fridge-freezer. However, until recently these improvements have been more than offset by three other factors (DTI, 1998; ECU, 1997; ONS, 1998):

- an increase in the *number* of households (there was a 30 per cent increase in the number of UK households between 1970 and 1995);
- an increase in the *ownership* of fridges, fridge-freezers and freezers within each household;
- a change in the *pattern* of ownership, from predominantly fridges in the 1970s to fridge-freezers in the 1990s, which make heavier demands on electricity use.

What are the implications for future patterns of demand? Have a look now at Figure 7, which displays the trends in UK electricity consumption for different categories of refrigerator and freezer from 1970 to 2020. For the period 1970 to 1995 it shows both the rise in total demand and the shift from refrigerators to fridge-freezers. The dashed lines from 1996 are *projections* of *future* demand to the year 2020; that is, they are estimates based on certain assumptions. The figure predicts that consumption will decline steadily. It is based on recent ownership patterns and consumption trends with the modest assumption that consumers will become more energy conscious and manufacturers respond to government initiatives. How realistic is this? In 1995 the European Union introduced mandatory **energy labelling** for domestic cold appliances and in 1999 minimum energy standards (corresponding mostly to energy class C). Energy efficiency improved markedly after 1998 to meet these standards leading to the reductions in electricity use by cold appliances seen in Figure 6.

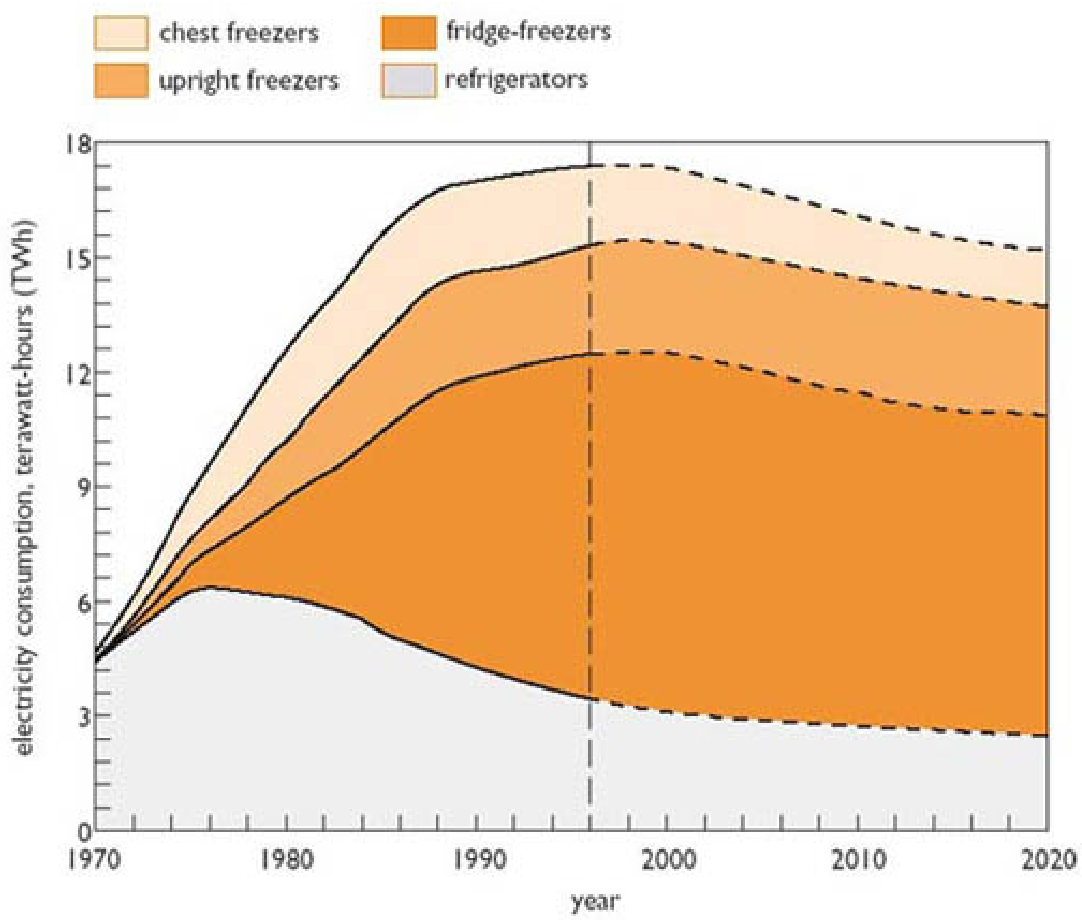

Figure 7 Electricity consumption in cold appliances, business-as-usual scenario, UK, 1970–2020.

So far, so promising. There is considerable scope, however, for further energy savings if consumers were simply to buy the most efficient appliance available. The cold appliance group, together with lighting, has been identified as having the greatest potential for household energy saving of all electrical appliances. The researchers of the Environmental Change Unit at Oxford University (ECU, 1997), call these savings the **economic and technical potential** or **ETP**. According to them, if the ETP of the UK cold appliance group is realised, by the year 2020 its electricity consumption could fall to less than a quarter of what it is now, which would represent a dramatic change.

Of course the *potential* for saving is not the same as its realisation. Both consumers and manufacturers would have to be whole-heartedly committed to energy saving. In practice, when people buy consumer goods they have other things to consider, like cost and reliability. Have a look now at Figure 8. This gives the results of a small survey where people were asked to choose (from a checklist) the most important factors to influence their choice when buying a cold appliance. As you can see, energy consumption is only fourth in the order of priority. Each prospective buyer of a fridge or freezer may have their own set of criteria, but on one point we can be fairly sure: all will be considering factors other than just energy efficiency.

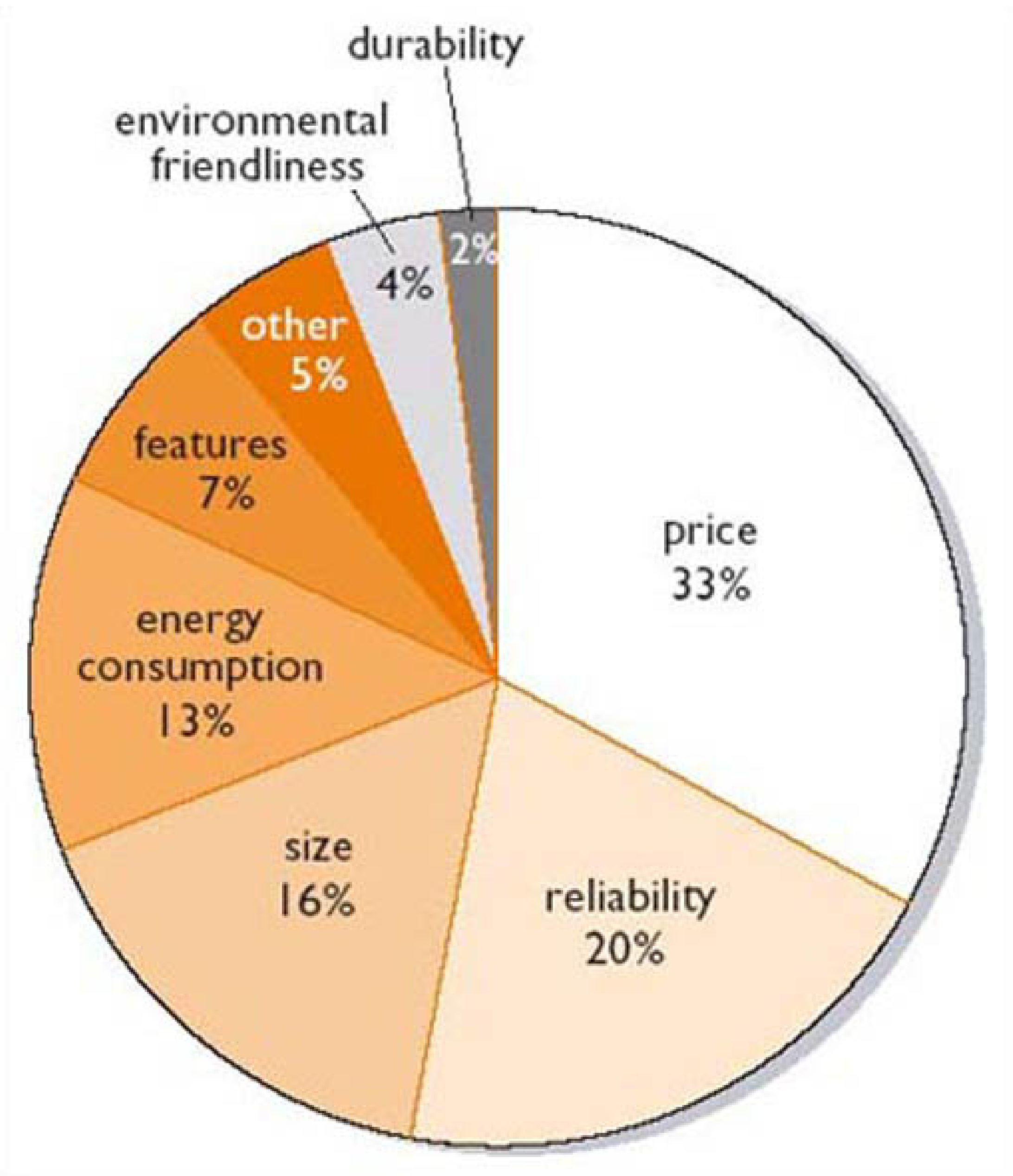

Figure 8 Most important criteria when buying a fridge-freezer.

4.4 Discussion

In this second case study, I have described two different trends in energy use by cold appliances over the last few decades. On the one hand the efficiency with which appliances use electrical energy has improved but, in spite of this, their consumption of electricity has increased significantly in recent decades. Since 2000 consumption has started to decline, probably as a result of the introduction of minimum energy standards. The trend will only continue if we demand and use the most energy efficient machines.

The focus of attention in this section has been on the *end use* of electricity and the consumer, but I wouldn't like to give the impression that this is the only approach to the energy problem. There is also plenty of scope for reducing our reliance on fossil fuels at the supply end, for example by changing to renewable sources of energy such as wind and water power. Both approaches will almost certainly be part of any move to a sustainable use of energy. What I hope I have been able to demonstrate in this case study is that there is considerable potential for energy savings.

4.5 Global climate change

I would like to turn now to the possible consequences of our use of energy for global climate change. Our pattern of energy use relies heavily on burning carbon-based fossil fuels, releasing carbon dioxide which spreads evenly around the globe and builds up slowly in the atmosphere. Carbon dioxide is a **greenhouse gas**, which means that it has the potential both to warm the atmosphere and to change our global climate. It is not the only greenhouse gas but is the most important of those emitted through human activity – accounting for over half of the human induced **greenhouse effect**. This effect and its relation to global warming is explained in Box 2 which also discusses CFCs and the ozone hole over the Antarctic: these two effects – ozone loss and global warming – are often confused.

Box 2: What exactly is 'global warming'?

(Many of the terms in this box are defined in the *Glossary.)*

The Earth sits in space in a temperature balance between the searing hot surface of the Sun (about 6000°C) and the bitter cold of deep space (around −270°C). Life on Earth has adapted to its average surface temperature of about 15°C.

The Sun emits a range of wavelengths of radiation, ranging from ultraviolet light with wavelengths shorter than 350 nanometres (nano=10^{-9}), through visible light to short-wave **infrared radiation** with wavelengths of 1000−2000 nanometres (Figure 9). Of this incident energy, about 30 per cent is simply reflected back into space. The remainder is absorbed by the atmosphere and the Earth's surface. Eventually, this energy is also re-radiated back out to space, but this time as long-wave infrared radiation, with wavelengths of over 10,000 nanometres. We tend to forget about this outgoing radiation until we encounter a ground frost on a cold clear night as the heat radiates first to the cold upper atmosphere (at around −20°C) and then out into space.

This re-radiation is partially blocked by a number of so-called greenhouse gases in the lower atmosphere which are to varying degrees opaque to long-wave infrared radiation. The fact that they do this means that the Earth is about 35°C warmer than it would be without them (hence the 'greenhouse'). The most important of these is water vapour. A cloudy sky is very good at preventing a ground frost on a winter's night. Other naturally occurring greenhouse gases are carbon dioxide, methane, ozone, and nitrous oxide. Some of these are also produced by human activities:

- carbon dioxide from the burning of fossil fuels and forests;
- methane produced by cattle, rice paddy fields, decomposing rubbish and leakage from natural gas pipelines;
- tropospheric ozone produced by traffic pollution;
- nitrous oxide produced from agricultural fertilisers and the manufacture of nylon;
- CFCs (which do not occur naturally at all).

The debate about climate change (see Section 3.4 below and Box 3) is concerned with the enhanced greenhouse effect due to gases added to the atmosphere by human activity. More carbon dioxide will increase the blocking of outgoing infrared radiation and require a rise in global temperature to restore the equilibrium.

But don't CFCs just cause the ozone hole?

Many people confuse the ozone hole with global warming, because two of the key players, CFCs and ozone, feature in both stories. Even worse, ozone turns up again in urban smog. Let's run through the differences.

Most of the ozone in the atmosphere is contained in the stratosphere. That is a very cold region extending from about 15 to 50 kilometres above the Earth's surface (jet airliners mostly fly at under 10 kilometres). It is the stratospheric ozone that mainly filters out the harmful ultraviolet rays of the Sun (Figure 10). CFCs attack and destroy this ozone in the very cold stratospheric conditions over the Earth's poles, creating the'ozone hole'.

However, CFCs also strongly absorb long-wave infrared radiation, making them important anthropogenic greenhouse gases. This effect takes place all over the atmosphere and all over the globe. This has made it doubly necessary to phase them out.

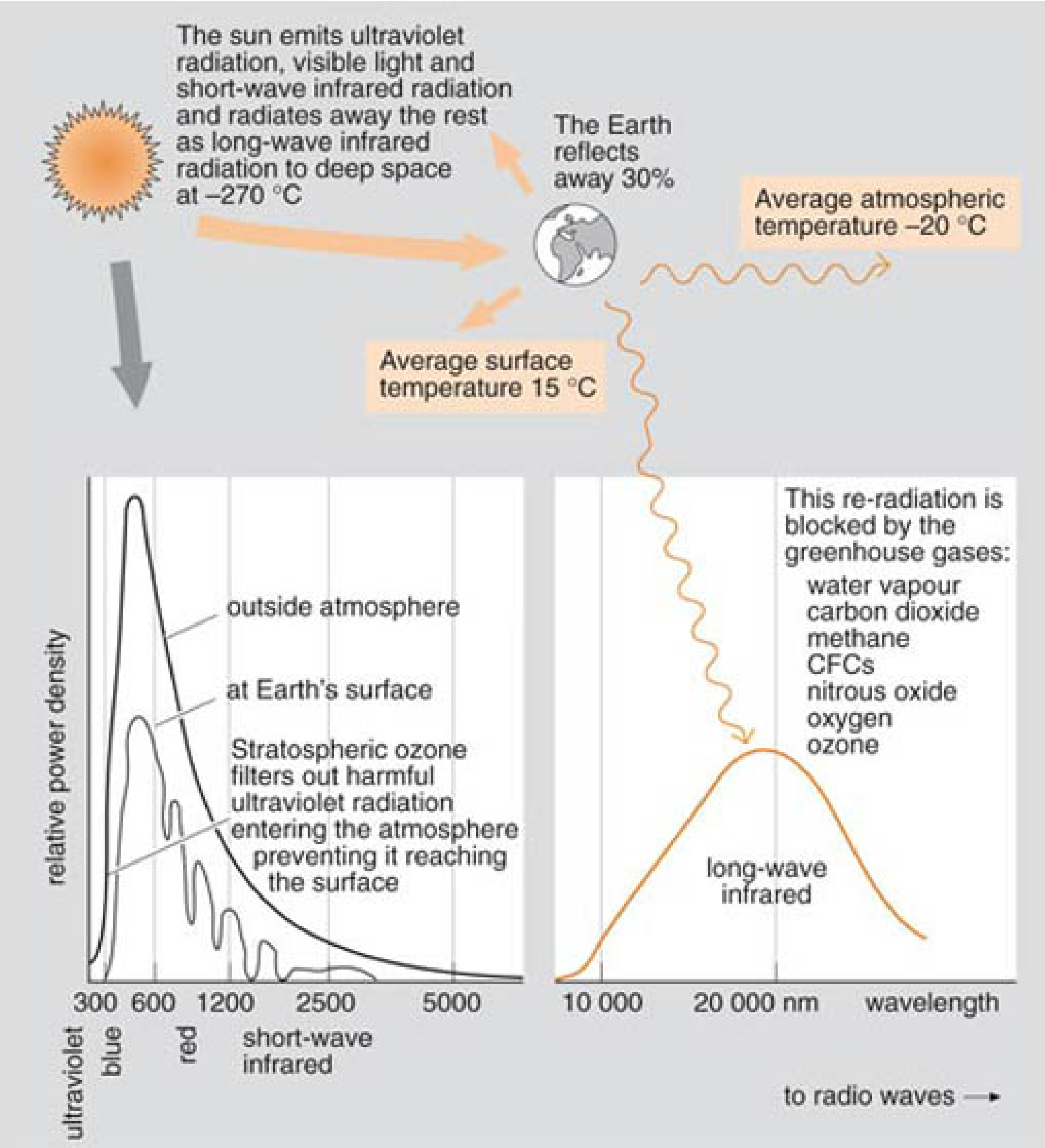

Figure 9 Radiation to and from the Earth.

Is ozone a good gas to have around? Obviously having plenty in the stratosphere keeps the Sun's ultraviolet rays at bay, but down on the Earth's surface it acts as a powerful oxidising agent, destroying vegetation. Industrially it is commonly used as a bleach and as a disinfectant for swimming pool water. 'Tropospheric' or low-level ozone is a particularly toxic ingredient of the 'photochemical smog' that occurs over cities such as Los Angeles, Mexico City and Athens. Reducing this kind of pollution is a key concern in the search for cleaner methods of transport.

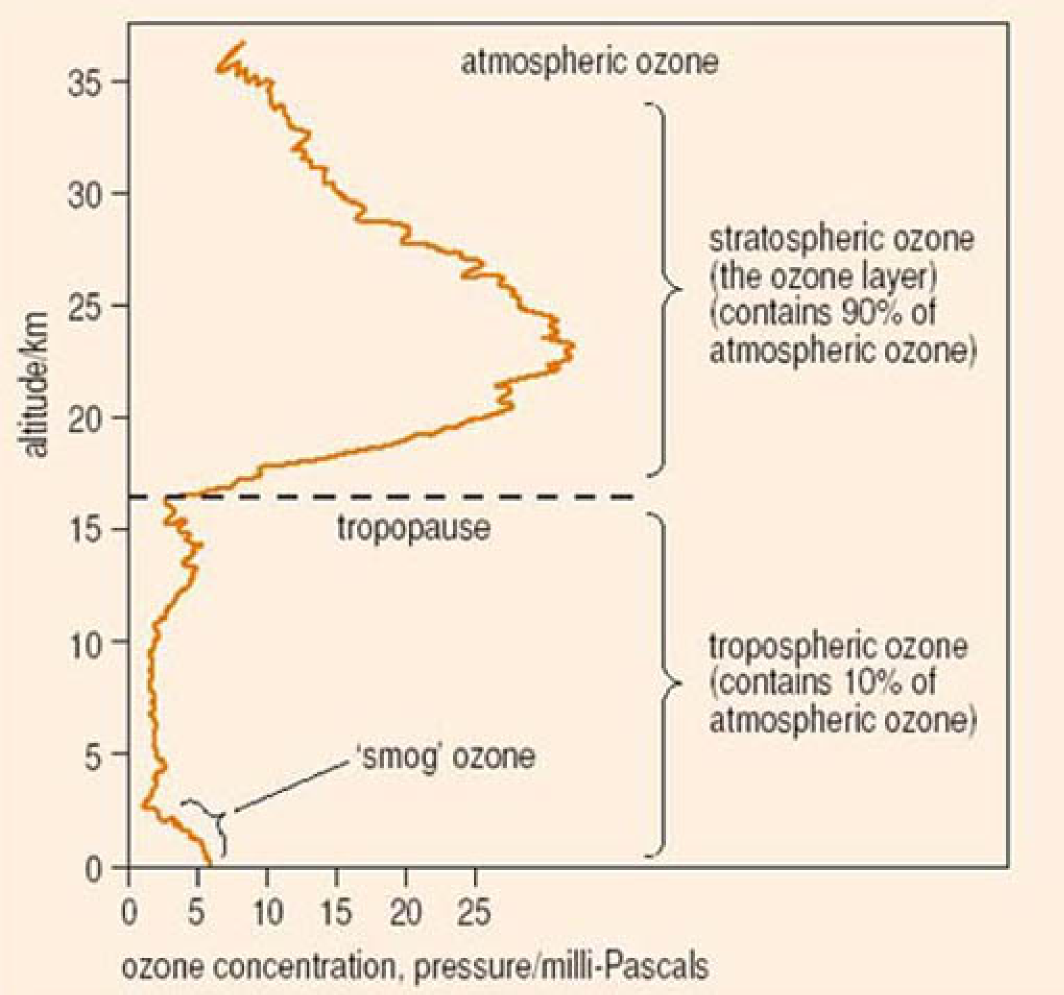

Figure 10 Density of ozone in the atmosphere.

Exercise 3

The aim of this exercise is to help sort out any confusion between global warming and ozone loss.

1. List in turn the gases associated with human-induced global warming and ozone loss, and identify the main gas or family of gases involved.
2. Identify (but do not attempt to explain) the chief mechanism thought to cause human-induced global warming and ozone loss respectively.
3. State in which part of the atmosphere each effect mainly takes place.
4. Finally, which gases are most likely to be involved in both effects?

1. The main gases associated with human-induced global warming are carbon dioxide, methane, nitrous oxide, tropospheric or ësmog' ozone and CFCs. Carbon dioxide is the most important of these. The most important family of gases involved in ozone loss is that of the CFCs. The other family mentioned in Box 1 is the HCFCs. In both cases you may know of other gases that have been identified. Note that we have not included water vapour here which of course occurs naturally, but is not emitted in significant amounts as a result of human activity.

2. The mechanism thought to cause human induced global warming is the greenhouse effect (strictly speaking the enhanced greenhouse effect), which is why the gases listed in the first part of (a) are called greenhouse gases. Ozone in the stratosphere is destroyed in certain circumstance by CFCs, particularly when the temperatures are very low. The details are extremely complex and we will leave it at that.
3. The greenhouse effect mostly takes place in the lower part of the atmosphere, or troposphere, which contains most of our atmosphere and most of the greenhouse gases. Ozone loss refers to the destruction of ozone in the stratosphere. Again the reason is the same – most of the ozone occurs in the stratosphere.
4. The gases most likely to cause confusion are, first, the CFCs, which contribute both to global warming and ozone loss, and secondly, ozone, which occurs in the stratosphere where it serves a vital purpose and is the 'victim' of depletion by CFCs. Ozone also occurs in the lower atmosphere where it forms summer smogs and is also a powerful greenhouse gas. There are other interactions – global warming and ozone loss are both very complex phenomena, but once again we had best leave it at that.

There is also considerable uncertainty in making the links between increased levels of carbon dioxide in the atmosphere and forecasts of global warming and climate change. For example, there are difficulties in modelling some key aspects of global climate, such as the interactions between oceans and the atmosphere and the behaviour of clouds. There are also problems in achieving a realistic forecast of human population and economic activity far into the future to arrive at the projections of future carbon dioxide emissions on which the models rely. Indeed, scientists are not agreed on the extent to which we are currently experiencing global climate change. (There is also a minority who still question the reality of greenhouse gases as a significant cause of climate change, though many of their arguments have now been answered.)

What this means is that there exists a major *threat* of change to our climate, but significant *uncertainty* as to its extent. In spite of the inability to provide precise forecasts, the great majority of scientists and policy makers decided at the 1992 Earth Summit in Rio de Janiero to act on this issue, and made their first, tentative agreement five years later at **Kyoto**. Box 3 indicates some of the likely impacts of climate change.

4.6 Global climate change continued

Box 3: Some impacts of global climate change

Record global temperatures

The global mean surface temperature of our planet has been rising steadily for 30 years. According to climate scientists, who have constructed a reliable global temperature series from 1860, nine of the ten warmest years in this long record have occurred in the last ten years, i.e. up to and including 2004. Global temperatures are now 0.7°C higher than a century ago. This may not sound much but climate scientists are now confident they are detecting the first signs of induced climate change.

Global climate models, such as those used by the Meteorological Office's Hadley Centre, show clearly that global temperature rise during the twenty-first century depends in large part on the greenhouse gases emitted as a consequence of human activity over the next few decades. Projections for the *additional* temperature rise this century suggest a range from about 2 to 5°C is likely (but will be higher over land than the oceans). What are the consequences of such an outcome? For simplicity we'll concentrate on one region, Europe.

Regional impacts: Europe

In recent years Europe has experienced a series of extreme weather events. In December 1999, northern and central Europe were hit by three intense windstorms, resulting in widespread damage, 200 fatalities and losses estimated at 18 billion euros. In 2002, 15 major floods occurred in Europe, most notably the August floods in central Europe, leading to 250 fatalities. In 2003 an unprecedented heatwave hit western Europe from June to August. Temperatures over 40°C were common and even reached 38.5°C (1O1.3°F) in Kent on 11 August, the highest temperature ever recorded in the UK. The summer heat lead to widespread forest fires and agricultural losses, and to an estimated 201,000 excess deaths, including 2100 in the UK, mostly amongst the vulnerable elderly population.

Are these events a sign of climate change? Not necessarily, although more frequent heatwaves and summer droughts and more incidents of intense rainfall are predicted for much of Europe. Wetter winters are also expected in the north, but whether this will lead to more storms is not clear. However, several points about climate change are illustrated. Firstly, extremes of weather can be more significant for both natural ecosystems and society than changes to the mean. Secondly, climate change is not only about warming, changes to rainfall patterns and water availability can often be more important. Thirdly, in both natural ecosystems and society some sectors are more sensitive and vulnerable to climate change than others, although there will often be winners as well as losers: for example, elderly people are less likely to die in Europe during milder winters.

The summer of 2003 was 2.3°C above the 1960–1990 mean. Without climate change it could be expected to occur once in a thousand years. With climate change it is only a matter of time before a 2003-type summer becomes the average, and this could occur as soon as the 2040s if nothing is done to reduce emissions. What would a hot summer then be like?

Changing the climate system

At some stage, if climate change is allowed to proceed, tipping points will be reached in the climate system – a system that links oceans, ice, atmosphere and biosphere – leading possibly to irreversible changes. Two specific dangers in the northern hemisphere have been identified: the melting of the Greenland ice cap, which would raise sea-levels by 7 metres, and closing down the thermohaline circulation, the ocean conveyor that drives the warm currents in the North Atlantic. Best estimates are that the former is almost certain to happen (but over many hundreds of years), while the latter will only partially close down and its effects will only slow the warming over Europe, not lead to colder conditions. None of this is known with any great confidence, but it is clear that the more climate change proceeds the greater the risk of permanent alterations to the climate system.

(Sources: Adapted from Research Reports by the Hadley Centre (the UK's Government centre for climate change science), 2003 to 2005.)

There is another reason why global climate change is difficult to deal with, and that is the length of time most greenhouse gases persist in the atmosphere, which for carbon dioxide and most other greenhouse gases is of the order of a hundred years. This means that our grandchildren, and their grandchildren, will suffer the climatic consequences of the emissions that we are producing now. It can be difficult for policy makers to act decisively now when the effects of such changes are both uncertain and likely to have most impact long after they have gone. There is also a judgement to be made between acting now and bearing the costs, and delaying – with the risk of harm to future generations if the delay is too long – in the hope of being able to take more effective action later. There is no simple answer to this type of situation, but there is an historical precedent in the precautionary principle approach taken by the international agreement to protect the ozone layer, where, as we saw in Case Study 1, another group of long-lived chemicals, CFCs, posed a direct threat to the global environment.

I have used the first two case studies to look in some detail at two difficult global environmental problems, with occasional forays into the past to get a better perspective of where we are now. In the process we have also had to explore some technical matters, and confront a few fundamental concepts. For the last case study I am again going into the past, this time to look for some wider and perhaps less familiar consequences of the Industrial Revolution. Although many of its immediate effects were local, other influences spread across the world as new forms of transport and communication allowed international trade to flourish. Together, trade and technology transformed the agriculture and economies of much of the world in the nineteenth century. Part of that story is linked to the early history of refrigeration, and, in the final case study, to its effect on a distant country not usually associated with the Industrial Revolution.

5 Case study 3: Some early uses of refrigeration

5.1 Food preservation and the development of refrigeration

Most societies have had traditional methods of preserving food: drying, baking, pickling, salting, smoking, the use of sugar, and in cold climates, freezing or chilling, with the use of ice houses in the summer. These techniques were usually carried out at a local level, which meant that most perishable food was consumed near to where it was produced, and any food processing was usually small-scale and localised. Cattle and livestock, for example, were moved 'on the hoof' from their pastures to abattoirs, even in the largest cities. Two major industrial preservation techniques were developed in the nineteenth century in response to a demand for longer term preservation and longer distance transport of food. The first, canning, was developed initially for transport of food in early nineteenth-century France, to meet the demand of Napoleon's revolutionary armies. The technique arose from a competition – an early example of Government-sponsored innovation! Until then armies had to live largely from the land they moved through, but the technology was soon adopted by other nations and their navies (Chant, 1989, pp. 253–256; and Heldman & Hartel, 1997, p. 3).

The second technique, refrigeration, was originally used in the 1870s, by industrial food processors who were looking for a means of storing perishable goods. An early example was the creation of refrigerated storage space for the newly industrialised abattoirs of Chicago in the USA. The technology was then quickly adapted to transporting carcasses across the continent by rail, and also across the Atlantic to Europe by steamship. With the advent of railways and steamships, the way was open for the transport of frozen produce to Europe from as far afield as the southern hemisphere. The techniques of refrigeration were soon applied to the processing and transport of perishable food from South America, Southern Africa, Australia and New Zealand. The first shipment of frozen meat was mutton from Argentina to France in 1877, followed soon after by 40 tonnes of beef shipped from Australia to England in 1880. In New Zealand the Tomoana meat preserving works was established on South Island in 1881 and twenty thousand sheep were processed in the works in the first year, with the freezing of meat started in 1884. The first refrigerated cargo sailed from South Island in February 1882 with 4500 mutton and 450 lamb carcasses bound for Britain. The new industry took a while to develop, and hadn't perfected its techniques – frozen meat was inferior to fresh (until Clarence Birdseye, of popular fame, inspired by the quality of naturally frozen meat on a wartime visit to Labrador, developed a quick-freeze technique which eliminated the damage from the formation of large ice crystals and led, eventually, to today's frozen and chilled ready-prepared meals) – but was in full swing by the 1890s.

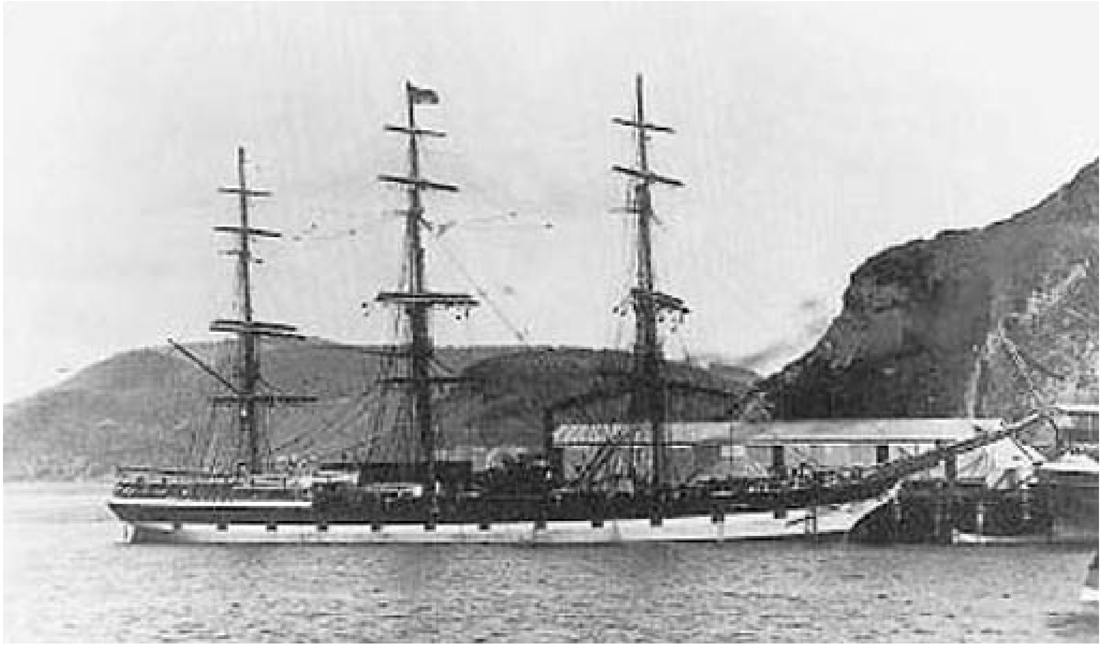

Figure 11 The first refrigerated cargo to be conveyed from New Zealand to Britain was carried aboard the Dunedin, which sailed from Port Chalmers on 15 February 1882. 4460 mutton and 449 lamb carcasses arrived on 24 May.

5.2 New Zealand's changing environment

In this study I want to explore some possible effects of this new trade on the environment of one of the countries involved. I've chosen New Zealand, partly because the developments we have just been discussing happened only a few decades after the first large-scale settlements of Europeans, and had a strong influence on the direction of its economy. Some background information will help to set the scene.

New Zealand consists of two mountainous islands with a total area similar to that of the British Isles, but a population of little more than four million. Its popular image is of a country that enjoys a pristine environment, clean air, mountains, rushing rivers, green pastures and of course sheep. This is only partly true, but without wishing to reinforce a stereotype, it is the sheep which have had the major impact on the country's landscape.

New Zealand has only recently been settled by humans. The first wave of settlers, 700 to 800 years ago, were Polynesians: hunters, gatherers and explorers who became known as the Maori. The second wave, called 'Pakeha' by the Maori, were mostly of European origin. Their numbers increased rapidly when planned settlements from Europe were started in the early 1840s. In 1840 the estimated population of Maori was between 100,000 and 200,000, while the Europeans numbered only 2000. By 1881 the Maori population had been reduced by epidemics and warfare to less than 50,000 while, encouraged by the policies of the British government and the local administration, the European total had reached nearly half a million, and rose to over a million by 1911.

Both waves of settlement had major impacts on the native **flora and fauna**, particularly through hunting and **deforestation**, but the settlement by Europeans was much more rapid and occurred during the later phase of European industrialisation. A major driving force for settlement and the economy was livestock farming, particularly of sheep and cattle. By the 1870s wool accounted for over half of New Zealand's exports, but it proved to be an unpredictable export market. The long agricultural depression of the 1880s led farmers and colonial governments to search for more reliable markets. The arrival of refrigerated transport proved timely and the export of frozen lamb and mutton played a major part in providing farmers with the confidence to continue expanding pasture land for sheep farming.

Figure 12 Grass seed being sown in newly burnt hill country. This was an important seasonal occupation as pasture farming developed during the latter part of the nineteenth century.

The development was not without its costs, and, indeed, it could be said that the massive growth of pasture lands that took place in the 1880s and 1890s,while the trade in frozen meat became established, transformed the ecology and landscape of New Zealand.

> 'In a single intensive decade, from 1890 to 1900, 27 percent of New Zealand's existing forest (or 13 percent of the total land area) was cleared, reducing the forest area from 13 million hectares to 9.5 million hectares. The deforestation rate during this period was four times the recent rate in tropical Asian rain forests. The number of farms rose quickly from around 10,000 in 1871 to more than 80,000 in 1921 when the total occupied area reached its natural limit – some 17.6 million hectares. This occupied land included several million hectares of remnant indigenous forests, mostly in marginal (steep) areas, many of which were subsequently cleared to expand pasture. Burning was the prime means of forest clearance, accounting for probably 90 percent of New Zealand's deforestation. Pastoral landscapes that look idyllic today were clouded by wood smoke a century ago. When the smoke cleared, it left a vista of blackened hillsides and charred tree skeletons'
>
> (Taylor & Smith, 1998, adapted from Box 8.1, p. 8.31)

Nor were these effects transient. Much of the modern landscape of New Zealand was created in the last few decades of the nineteenth century – as this selection of key points from *The State of New Zealand's Environment, 1997* in Box 4 illustrates.

5.3 Settlement, deforestation and endangered species

Box 4: Some indicators of New Zealand's environment*

The proportion of New Zealand converted to farmland is large by world standards (52 percent compared to the world's 37 percent in 1993). Although our human population density is comparatively low (13 people for each square kilometre (km^2) compared to the world's 43) our livestock density is high (180 sheep per km^2 compared to the world's 14 and 35 cattle per km^2 compared to the world's 10). This amounts to 13 sheep and 3 cattle for every person, and makes pastoral agriculture the country's main land use.

* The figures presented here are based on careful definitions, which can always be challenged. Without access to that background information the safest approach is to accept the figures as a reliable guide, but not necessarily to the accuracy given.

Since human settlement approximately 700–800 years ago, the indigenous forests, which once covered about 85 percent of the land area, have been reduced from some 23 million hectares to approximately 6.2 million (23 percent of the land area) – mostly confined to mountainous areas and to some low-lying parts of the West Coast, Southland and Northland. In most areas lowland forests have been reduced to fragments and will need considerable expansion if **biodiversity** within them is to be sustained.

Grasslands covered 1–2 million hectares (roughly 5 percent of the land area) before humans arrived but expanded to almost 8 million hectares as a result of deforestation by early Maori fires. Further deforestation in the past 100 years by farmers and timber millers has extended the grassland area to 14 million hectares – over 50 percent of the total land area.

The main source of pressure on water is pastoral agriculture which has polluted many surface waters and some groundwater with sediment, animal waste and nutrients, and has also increased flooding and erosion in many areas by removing deep-rooted vegetation from hillsides and riverbanks. (The use of irrigation water, mainly for pasture, is also a source of pressure on water levels in some South Island rivers, as is land drainage for agriculture which has caused an 85 percent reduction in New Zealand wetlands.)

Floods can occur in any season, and in all regions of New Zealand. The rate of flooding increased 50–150 years ago following widespread replacement of forests, scrub and tussock with shallow-rooted pasture grasses. Despite extensive river and catchment control schemes, damage from flooding is estimated to cost at least NZ$125 million a year.

(Source: Taylor & Smith 1998, pp. 7.6, 8.5 & 8.6).

From a land that was originally 85 per cent forested and occupied by mostly unique species of plants and animals, New Zealand has changed into a largely *managed* landscape, two-thirds of which is given over to farming and forestry with introduced species. The majority of this land is now under pasture, much of it on hilly and mountainous terrain. Many of the key effects on New Zealand's environment arise from this intensive period of human settlement and the introduction of livestock in the late nineteenth century. The combination of habitat loss and the introduction of new species has had a dramatic effect on the native flora and fauna. In particular:

- The displacement of native forest and grasses by agriculture led to loss of habitat and severe pressure for many native species. Over 30 species of land birds are known to have disappeared after the arrival of the Maori, and since European settlement a further 16 land birds have become extinct, together with a native bat, one fish, at least a dozen invertebrates and possibly as many plants.
- Just as significant, the new pressures from the settlers and their agricultural practice has greatly increased the number of species threatened with extinction. The main threat comes from the loss of suitable habitat or its fragmentation – the agricultural landscape is hostile to many native species. In addition, introduced pests and weeds prey on or compete with native species or destroy their habitat. The Kea is one of the endangered species:

> 'Many [native species] are still coping with the fallout from habitat destruction and predation. One such is a native parrot, the Kea *(Nestor notabilis)*. Once widespread in the South Island, its original range was first reduced by Maori deforestation, then by the conversion of the high country into sheep pasture.
>
> Last century, when it became known that some Keas attack sheep, a bounty was paid for their destruction and continued to be paid well into this century. At 10 shillings a beak in the 1920s (equivalent to NZ$65 or £20 today) Keas provided a lucrative living for bounty hunters … it is estimated that about 150,000 Keas were killed between 1870 and 1970, bringing the population down from about 50,000 to 5,000–15,000 today.
>
> The Kea only received formal protection in 1986 after an agreement was reached between the Department of Conservation and high country farmers, in which the Department undertook to control 'rogue' birds. Keas were also shot [as a pest – they have powerful beaks with which they like to test to destruction modern materials such as rubber] in the early days of ski-field development but today most ski-fields are Kea-proofed.'
>
> (Taylor & Smith, 1998, p. 9.30)

Figure 13 The Kea, the only alpine parrot

The Kea is a unique bird. It is highly intelligent and curious about human artefacts – both a strength and a weakness for an endangered species. It is the only example in the world of a most unexpected adaptation: an alpine parrot. To what extent do you think that the development of refrigeration can be blamed for the current state of the environment in New Zealand, including the near demise of the Kea?

Exercise 4

Have a look now at Figure 14. How well does it represent the processes which have led to the decline of the Kea? Spend five minutes to review and list other possible influences on this linear chain of cause, then draw a modified version of Figure 11 which incorporates the additional factors.

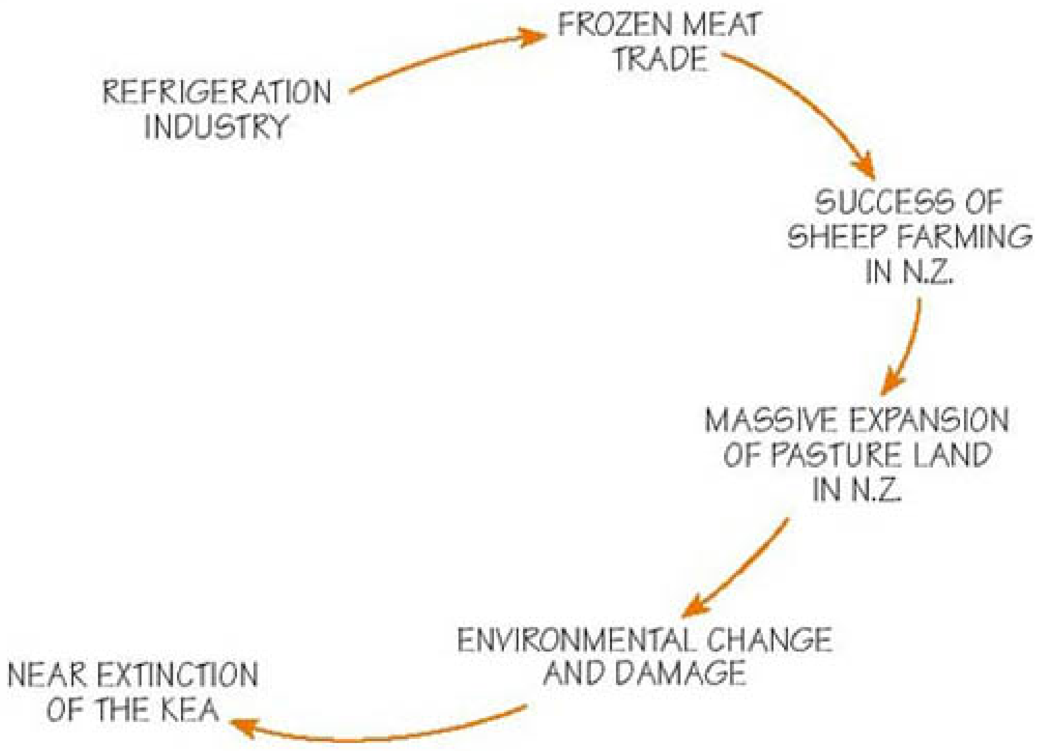

Figure 14 A causal chain from the development of the refrigeration industry to the decline of the Kea.

The short answer is that it is both an over-simplification and misleading to suggest, as Figure 14 does, that the problems faced by the Kea are solely the result of the development of refrigeration. While a case can be made for each causal link in the diagram, it is extremely unlikely that these are the *only* factors at work. At each point in the diagram there are likely to be several other contributory factors. The true picture is much more complicated and the diagram should represent multiple causes for each stage (if they are known). My own attempt, a **multiple-cause diagram**, based mostly on information given so far, is shown in Figure 15.

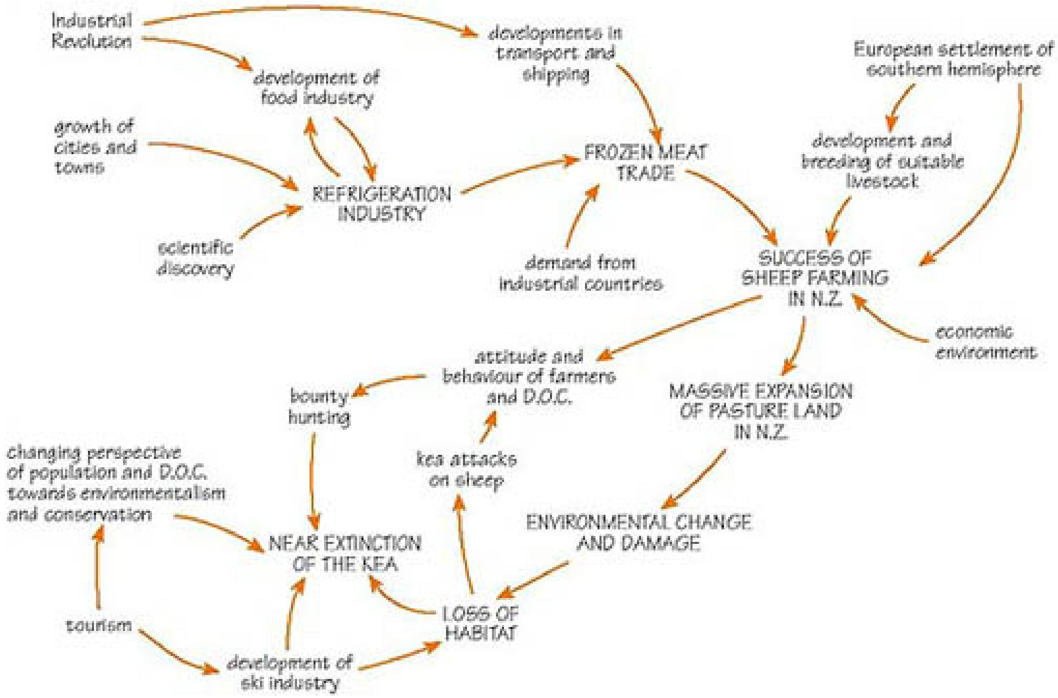

Figure 15 Figure 14 modified to include the possibility of multiple causes.

5.4 Discussion

We seem to have travelled a long way from the Industrial Revolution in Europe, but many of the impacts on New Zealand's ecosystems described here can be traced, in part at least, to reverberations from these developments.

What lessons can be drawn from this example? Perhaps I should start by emphasising this is not meant to be a complete account of the environmental history of New Zealand. For example, I have not discussed any responses from the population once they realised that harm was being done. In New Zealand concern for the environment started early and is part of New Zealanders' cultural heritage. The example I have chosen is necessarily selective and simplified to allow me to make a few points.

First, as you have probably recognised, what happened in New Zealand in the nineteenth century is being experienced today in countries whose tropical and temperate rain forests are under threat. Of course similar events occurred in most countries at one time or another under the pressures of population, the demand for goods, and the use of more powerful technologies in agriculture and industry. This case study was chosen because the environmental changes we have seen, while mirroring what happened in Europe and elsewhere, were telescoped into a short period. And they occurred recently enough to be well documented.

Secondly I believe it illustrates the complexity of the chains of interlinked events. We have seen that ecological pressure on an individual species in a once isolated country could not be attributed to a *single* cause – the development of refrigeration. When we are dealing with the interaction between human society and ecosystems, a simple cause and effect link is most unlikely to tell the whole story. This inherent complexity creates particular difficulties for those trying to manage or mitigate these pressures. If all the major causes are not identified and countered, the effort may be wasted, and there is always the risk that any measures taken may create further significant problems of their own. There have been many cases, for example, of exotic species being introduced to combat a known pest, where the newcomer proves to be a worse nuisance than the problem it was meant to solve. One such case is the South American cane toad. It was introduced in the 1930s to the sugar cane fields of Queensland in Australia, as an early attempt at biological control, in this case of the sugar cane beetle. It wasn't a success in controlling the beetle, but nevertheless thrived in its new surroundings and has steadily expanded its range through northern Australia. Because it produces extremely poisonous toxins at all stages of its life, any native predator that attacks it usually dies, as do domestic pets, and it is not particularly popular with the human population either.

This illustrates the other side of that argument, namely that the introduction of an apparently simple change into economic or ecological systems is likely to have a multiplicity of different *effects*. No doubt many of these can be anticipated or modelled, but rarely all of them.

My final and related point is that technological changes can have a much wider impact on the economic and social organisation of societies than their direct effects (that is, the impacts of the material transformations and services they provide) would suggest. Here we have seen an example of this: developments in two technologies which are often linked together – transport and food processing – interacted with the social changes associated with nineteenth-century settlement to influence the economic direction of New Zealand (and not just New Zealand of course), and through it the environment. Similar influences (for example, the globalisation of trade and markets by **transnational companies**) are still at work around the world.

SAQ 2

Take a few minutes to scan through the discussion in Section 4.2, where I have attempted to draw together the lessons from the last case study. Then make notes of what you think are the main points that have been made.

Answer

When I did this myself, I identified four related points, although I had originally intended to make only three. They are:

1. The New Zealand example (of environmental impacts) occurred in a short space of time and is well documented – and can be used for a comparison with what is occurring today.
2. The interactions between human societies and ecosystems are complex and many factors are usually involved. A single cause and effect link is unlikely to be the complete explanation.

3. A related point is that an apparently simple change to an environment system may have many different effects. This creates difficulty for environmental management. Unless all the key effects are anticipated, unexpected and often unwelcome complications may occur.
4. Similarly, the introduction of a new technology may have far reaching indirect effects through its influence on society, as well as direct effects.

6 Finding a balance

6.1 The path to prevention

So far in this *Introduction* I have concentrated on some specific environmental issues, which has inevitably meant I have spent time looking at problems and their possible causes. A balanced account would look in similar detail at possible responses and solutions. The Greenfreeze example in Case Study 1 was one attempt at a solution. At the local scale, in the factory, scientists and engineers have always provided society with solutions to the problems of pollution and threats to public health. There is not space here to do more than summarise the types of approaches taken to dealing with pollution and other environmental problems but they do illustrate the growing sophistication of environmental managers in the face of our growing responsibilities for the environment.

The question I wish to address in this final section is: how do we balance human needs with those of the environment? My first answer is the practical approach – get rid of the damaging effects.

Earlier, in Section 1.3, I outlined some of the changes in environmental attitudes that have taken place since the Industrial Revolution, as both our impact on the environment and awareness of this have grown. These changing attitudes have been paralleled by the approaches taken to dealing with the problems by legislators and industry. Broadly speaking they fall into three categories. The first is characterised by '**laissez faire**' attitudes (essentially letting the environment absorb the problem). The approach of early human settlements has been called '**foul and flee**' – when environmental problems became obvious, people simply upped and moved elsewhere. In the industrial age it has been represented by two policies, '**concentrate and contain**' and '**dilute and disperse**'. The former is usually applied to landfill and the latter is reliant on air and water to dilute pollutants until they are no longer a threat. Both assume the environment can take the strain, and have failed badly when long-lived toxic chemicals have leaked from dumps, or concentrated in food chains instead of being dispersed.

The second broad category is the control of pollutants as they leave their source: the '**end-of-pipe**' approach. This has been successful when filters and scrubbers are applied to individual sources, for example removing sulphur dioxide from power station effluents to prevent acid rain, and is the principle behind catalytic converters for controlling vehicle emissions. However, this method can be costly.

The third category is based on the precautionary principle and aims to prevent pollution rather than cure it – particularly by reducing the material flows or substituting less harmful materials – and we have seen examples of these in the first two case studies. A variety of techniques can be applied to the design of industrial and economic processes from 'waste minimisation' to the use of 'clean technology' and come under the general heading of **preventative environmental management** (Jackson, 1996, pp. 58–83).

6.2 The hierarchy of human needs

A second approach is to look at the human needs and wants from a more theoretical perspective. One such model was developed in the 1950s and 1960s by Abraham

Maslow. Although it exists in many variants it is generally known as **Maslow's hierarchy of human needs**. In the most common interpretations it places the fundamental *material needs* of survival, such as food, shelter and safety at the base of a triangle, rising through *social needs* of belonging in human society, to *moral needs* of self-development at the apex. From our perspective this model offers two lessons. For those living in poverty, material needs, including services, will usually have the highest priority, though some, such as clean water and air and available fuel, are intimately related to the state of the environment. But for those who have escaped poverty and live in relative affluence, the so-called 'higher' needs, such as social and moral, do not necessarily require further material use. You might like to think about this in terms of where your money goes and what your priorities are. An interesting question arises with this Open University course. You may be studying it because it meets some of your moral aspirations for self-development, but possibly it also meets some of your social and material needs. What are the demands it makes in terms of material and energy use?

Although Maslow's model is more complicated than the brief interpretation I have given and has been criticised since it first appeared, I believe it reinforces a point made earlier on, namely the importance of focusing on the services made possible by energy. There are no laws of nature stating that affluence beyond a certain level is inevitably associated with an increase in energy use. Indeed, if you look at the *per capita* use of energy over the last few decades, it has *declined* in most industrialised countries, often reflecting a shift in the balance of their economies from primarily manufacturing to predominantly service based (As more manufactured products are imported from newly industrialising countries.) It is also worth noting that as our societies become more affluent they usually become less tolerant of environmental damage and pollution, and although the relationship between the two isn't simple, per capita levels of pollution are generally lower in richer countries than in poor ones. But are these tendencies strong enough for us to grow out of our environmental problems? Unfortunately, all the indications are that they are not, at least not without a drastic change of culture.

6.3 Sustainable development

The third approach to balancing human needs with environmental protection is to try to come to grips with what we mean by sustainability.

The most widely quoted definition of **sustainable development** is the one used by Gro Harlem **Brundtland** in the highly influential book *Our Common Future* (Brundtland, 1987):

> 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

While it would be hard to disagree with this definition, it is very broad and capable of many interpretations. Brundtland goes on to explain that it contains two key concepts:

> 'the concept of human needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and
>
> the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs.'

The idea of limits on the environment's ability to cope with our technologically serviced needs has been one of our central discussion points. The other concept – human needs – we have just begun to explore, though our case studies have concentrated on the UK and other industrialised countries. The Brundtland definition does make it clear that priority is to be given to human needs, to the poor in particular, but does not say how. Many have attempted to spell out the implications in more detail, as in the following definition, where the emphasis is slightly different:

> 'To promote development that enhances the natural and built environment in ways that are compatible with:
>
> - The requirement to conserve, even increase overall the stock of natural assets
> - The need to avoid damaging the regenerative capacity of the world's natural ecosystems
> - The need to achieve greater social equality
> - The avoidance of passing additional costs and risks to succeeding generations.'
>
> (Blowers, A., 1993, p. 6)

If we accept that human (and economic) development is an integral aim of sustainable development, the question still remains: where does the balance lie between human and environmental needs? We can use a familiar example to illustrate this point: the emission of greenhouse gases and its effect on global climate. In terms of the global climate, sustainability means that the changes must be limited so that neither the *rate* of change nor the *absolute* change of climate is damaging to ecosystems or humans and their economic activities. While there may be discussion about the precise figures, there is a general consensus that to achieve this a cut in *global* greenhouse gas emissions of more than 50 per cent is needed, and sooner rather than later. Now where should they fall? Considerations of equity (fairness) suggest that industrialised countries should bear the lion's share of the cuts, and that means they have to make cuts much deeper than 50 per cent, while the less developed countries are allowed to continue to develop. After all we cannot deny the inhabitants of India and China their 'right' to have a refrigerator. What we can do, given the political will, is subsidise their development so that they are able to use the cleanest and most effective technologies. Greenfreeze is thus a very positive example of what can be achieved, but, at the moment, it is an isolated example.

6.4 Technology and environment

At the start of this course I asked a simple question: am I damaging the environment by using my fridge? I warned that it wasn't my intention to give a simple answer that we should all stop using refrigerators or all carry on regardless. Instead, we have explored the issue more widely, calling on a range of ideas and background information in the Case Studies. It is time to review some of the concepts we have been using.

6.4.1 The dual nature of technology

Exercise 5

List the main advantages to you of using a refrigerator in your home, then list some of the potential environmental hazards that using a fridge might entail.

Your list of advantages will, of course, be personal and vary from individual to individual. Some of mine are:

- access to fresh milk for my coffee habit, frozen food and vegetables, and iced drinks;
- the need to make fewer visits to the shops for food (like many people today I don't seem to have too much 'spare' time).

Environmental hazards (some of these have been discussed before):

- The using up of materials and resources during construction and distribution.
- Energy consumption during use means greenhouse gas emissions.
- My fridge is over 10 years old so I expect, though I don't know, that it contains CFCs. When the time comes to replace it I will certainly make sure it is disposed of properly.
- Behaviour: Having a fridge (and freezer) certainly affects my shopping habits. It allows me to use more convenience foods and is a major reason (price is another) why I tend to go to a supermarket once or twice a week rather than visit local shops more frequently. I suspect I am not alone in this and I probably represent part of a general trend. The mass ownership of fridges in the UK has probably contributed to a general shift in lifestyle and consumption patterns. I am not sure whether this is for good or ill – probably a mixture of the two.

Clearly, it is possible to draw up a similar balance sheet of advantages and disadvantages (potential benefits and harms) for any given use of technology. This characteristic is sometimes called the *dual nature of technology*, a concept that applies not just to individual consumer durables such as a refrigerator or car, but to all levels from individual artefacts to industries and to the level of the global economy.

Many discussions today about the impact of technology on the environment can be quite polarised, especially where new technologies are involved. People are often strongly for or against the introduction of a particular technology, as recent controversies over the use of genetically modified crops or the possible radiation hazard of mobile phones have illustrated. The issues surrounding each case may be quite different but we appear to be confronted with a paradox when we make use of technology. While the introduction, for example, of a new consumer appliance or a new application of existing technology may bring obvious benefits to individuals or society, in turn it nearly always seems to expose us to new risks and dangers. When we use technology we appear to be dealing with a phenomenon that has a split personality, one with a potential for good, the other for harm.

6.4.2 A broad view of technology

This dual nature is not because machines or chemicals are inherently good or bad; it arises from the way societies decide to use them (or not). This makes sense if you take a broad view of technology, outlined at the beginning of this *Introduction*. This is the understanding that technology, and it's uses from artefacts to infrastructure, is the product of human and social action. It is a major driver of the development of societies and their economies, but the forms and directions these take are not inevitable.

6.4.3 Problems and solutions

These concepts apply equally to our interactions with the environment. As we have seen in Case Studies 1 and 2, our use of technology can contribute to environmental problems (the release of ozone-depleting chemicals and greenhouse gases) and at the same time is the basis of environmental solutions through the control of CFCs, HCFCs and HFCs, and improved energy efficiency. The general point is made by the following passage from Our Common Future, the report for the United Nations Conference on Environment and Development:

> 'The mainspring of economic growth is new technology, and while this technology offers the potential for slowing the dangerously rapid consumption of finite resources, it also entails high risks, including new forms of pollution and the introduction to the planet of new variations of life forms that could change evolutionary pathways. Meanwhile, industries most heavily reliant on environmental resources and most heavily polluting are growing most rapidly in the developing world, where there is both more urgency for growth and less capacity to minimise damaging side effects.'
>
> (Brundtland, 1987, pp. 4,5)

The scale and range of environmental problems we face are daunting, but, as Case Study 1 has shown, problems can be addressed and harm can be reduced, hopefully to safe levels. Technology can and should be used for sustainable development.

6.4.4 Environmental limits

There are many different definitions of what sustainable development means; you were given one in Section 5.3, and how this should guide policy. The underpinning concepts are: equity for human development, and limits on the capacity of the environment. The idea of environmental limits on the ability of the Earth's biophysical systems to cope with and adapt to pressures from human activity, whether from demand for natural resources, the waste products of modern economies, or from habitat modification and destruction, has been the constant theme of this Introduction.

6.4.5 Complexity

The final concept, discussed in Case Study 3, is the complexity of interactions between society, technology and environment, illustrated by Figure 14. A simple technical fix to a problem, such as the introduction of a harmless gas (Freon), or a new predator (the Cane Toad), can have many unintended outcomes. This is not an argument against innovation or for inaction, but for looking at every issue in a broad, systemic way, to involve all those likely to be affected and to understand the ecological and physical basis of the problem: to take the broad view of technology.

Exercise 6

You have now reached the end of this *Introduction*. What skills and concepts do you think you have learnt and developed from working through it? Take a few minutes to go over what these might be, then make your own, personal list.

Your answer will depend on what you knew before you started and on how conscientiously you followed the exercises and suggestions in the text. The results may surprise you.

This is my list, but you may well be able to think of others, including some more general points such as organising your study space and time:

- reading rapidly and in depth from technical extracts and arguments
- summarising and making notes
- using and interpreting a variety of charts, diagrams and symbols
- using and interpreting numerical and chemical information
- following some basic concepts in chemistry and physics
- thinking critically about some of the arguments put forward
- making sense of some highly complex systems and interactions.

Conclusion

In this *Introduction* we have explored the development of technology from the start of the Industrial Revolution to the present day. At the same time we have traced the increasing impact our industrial societies have had on our environment, and the role that science and technology has played in this. We have explored some major global environmental issues, in particular our dependence on the exploitation of fossil fuels, and have outlined some of the fundamental constraints on the ability of the environment to absorb the resultant emissions and waste products.

I have used three studies of refrigeration to illustrate some of these points and also to explore the breadth and complexity of their interactions. You could argue that our current use of cold appliances affects more than the home, that they are inextricably tied in to our use of supermarkets, town planning, globalisation of food and transport. As actors in this story, engineers, designers and technologists increasingly have to take a broad view of their role, while policy makers and the public need to be able to question decisions, and the assumptions that lie behind them. Whatever your expertise, as a concerned individual you now have the opportunity to explore in more detail some of the issues raised here.

Keep on learning

Study another free course

There are more than **800 courses on OpenLearn** for you to choose from on a range of subjects.

Find out more about all our free courses.

Take your studies further

Find out more about studying with The Open University by visiting our online prospectus.

If you are new to university study, you may be interested in our Access Courses or Certificates.

What's new from OpenLearn?

Sign up to our newsletter or view a sample.

For reference, full URLs to pages listed above:

OpenLearn – www.open.edu/openlearn/free-courses

Visiting our online prospectus – www.open.ac.uk/courses

Access Courses – www.open.ac.uk/courses/do-it/access

Certificates – www.open.ac.uk/courses/certificates-he

Newsletter – www.open.edu/openlearn/about-openlearn/subscribe-the-openlearn-newsletter

Glossary

Glossary item

Definition

atom

the smallest amount of a chemical element that still retains the properties of that element.

biodiversity

a contraction of 'biological diversity', in general it describes the variety of life on Earth and specifically the total sum of the genes, species, habitats and ecosystems in a given environment.

Brundtland report

a report for the United Nations on sustainable development, published in 1987.

carbon dioxide

a chemical compound consisting of carbon and oxygen. A molecule of carbon dioxide consists of one atom of carbon and two atoms of oxygen ('di' means 'two'). CO_2 is produced in respiration and combustion reactions and is consumed in photosynthesis. Carbon dioxide is the most important greenhouse gas released as a result of human activity.

chlorofluorocarbons (CFCs)

a family of compounds containing carbon, fluorine and chlorine atoms. CFCs are chemically inert and stable and were formerly used as refrigerants, aerosol propellants and in foams. Following the discovery that they are responsible for ozone layer depletion their production and use were banned in many countries.

concentrate and contain

to deal with pollutants by containing them in a comparatively small space and attempting to isolate them from the wider environment (the opposite of dilute and disperse).

DDT

dichloro-diphenyl-trichloroethane. A pesticide developed during the Second World War. It is highly effective, but it persists in the environment and can be fatal to fish and bird life. Due to this problem the production and use of DDT is banned in most countries. DDT is an organochlorine compound.

deforestation

the destruction of forests in order to use the wood or to clear the land for other use such as agriculture.

dilute and disperse

a method of dealing with pollution by discharging the pollutants into an environment where they disperse rapidly, reducing the potential for causing damage. This strategy can only be adopted after a thorough analysis of its impact on all aspects of the environment (see also concentrate and contain).

economic and technical potential

the savings that could be made by the widespread use of existing environmentally efficient appliances.

end-of-pipe

control of pollution by removing potential pollutants from an effluent stream (for example removing the NOx from vehicle exhausts or the sulphur dioxide from coal-fired power station emissions).

energy labelling

a compulsory EU labelling scheme for consumer products, such as refrigerators, that meet given levels of energy efficiency and, sometimes, other environmental or performance criteria.

energy standards

regulations specifying the minimum efficiency of electrical appliances (see also environmental standards).

flora and fauna

the plants (flora) and animals (fauna) in a given area.

food chain

a series of organisms beginning with plants where each stage feeds on the stage below it. In general, the series consists of plants–herbivores– carnivores

foul and flee

a way of dealing with pollution by carrying out a polluting activity until local pollutant levels become too high and then moving to another area and repeating the process. This was common in pre-industrial days, but began to be phased out during the Industrial Revolution.

Freons

a proprietary name (or trade name) for a particular brand of CFCs (chlorofluorocarbons).

global climate change

a warming of the global climate believed to be due to the accumulation of greenhouse gases in the atmosphere and caused by the releases of these gases through human activity.

greenhouse effect

mechanism whereby incoming solar radiation is trapped by carbon dioxide and other greenhouse gases in the Earth's atmosphere in the same way as heat is trapped by glass in a greenhouse.

greenhouse gases

gases which have the effect of warming the global climate. Without them the Earth's temperature would be some tens of degrees Celsius colder than it is now (and life would not have evolved in its current form), but current concern is about global climate change caused by their increase in the atmosphere since the Industrial Revolution. The principal greenhouse gas is carbon dioxide, others are methane, nitrous oxide and CFCs.

habitat

place with a particular kind of environment where a given organism lives, e.g. coniferous forest for the red squirrel.

HCFCs

or hydrochlorofluorocarbons. Designed to be a replacement for CFCs, they have a lower potential for destroying the ozone layer (typically less than a tenth), but most are strong greenhouse gases. HCFC use is to be phased out over the period 2020–2040 (see also HFCs).

heat

energy due to the temperature of a substance, and the kinetic energy of the molecules composing it. Also called thermal energy.

HFCs

or hydrofluorocarbons. Designed as a replacement for CFCs. As they contain no chlorine, they do not deplete the ozone layer and are not covered by the Montreal Protocol, but they are strong greenhouse gases (see also HCFCs).

hydrocarbons

compounds of hydrogen and carbon only. One of the main uses of hydrocarbons is in fuels. Methane, the simplest hydrocarbon, is the main constituent in natural gas.

Industrial Revolution

the transformation of the British economy from a rural to an urban one during the 18th and 19th centuries. This period was characterised by the development of industrial processes, the development of factories and the growth of cities.

infrared (IR) rediation

all bodies, including the Sun and the Earth, give out and absorb energy in the form of IR radiation. The infrared can be thought of as radiant heat and refers to radiation with a wavelength longer than that of light. The range of IR wavelengths given out by a body depends on its temperature and the IR from the Earth is quite different in quality to that coming from the Sun.

kilowatt-hour (kWh)

1 kWh is equivalent to the 'Unit' used in metering domestic electricity. It is a quantity of energy equal to 3600 kJ. (The energy consumed by an electrical appliance in kWh can be calculated by multiplying the power consumption (in kW) by the length of time (in hours) the appliance is operated for.)

Kyoto climate change protocol

an international agreement stemming from the 1997 climate change conference held in the Japanese city of Kyoto. Under this protocol, most industrialised countries agreed a legally binding obligation to reduce the emission of gases (particularly carbon dioxide) contributing to climate change.

laissez faire

in environmental tds, taking no action to control pollution but letting the natural environment absorb (and in some cases treat) the pollutant. In economic tds it means a belief that the workings of a free economic market will always produce the best result (as opposed to regulation by any agency).

Maslow's hierarchy of human needs

a way of looking at needs which stretches from basic needs of food, shelter and water at the base up to the higher needs of love and truth at the top.

molecule

the smallest part of a substance (chemical element or compound) which can exist independently.

Montreal Protocol

an international agreement signed in 1987 to phase out the use of CFCs and other substances that damage the ozone layer. This protocol has been signed by around 60 countries (but not by China or India).

organochlorine compounds

a class of chemicals that are products or unwanted by-products of the organic chemicals industry. Many of them are highly toxic and accumulate in the environment or in living things and degrade at a very slow rate.

organophosphates

a group of chemicals developed from nerve gases. They are used as pesticides and degrade much more rapidly than organochlorine compounds. However, the long-td environmental effects of organophosphates are not known.

ozone

a reactive form of oxygen whose molecules contain three oxygen atoms. Ozone is a pollutant in the lower atmosphere (troposphere), but its presence in the upper atmosphere (stratosphere) provides the protection from ultra-violet radiation necessary for life to have evolved on Earth.

ozone depletion (ozone hole)

a reduction in the level of ozone in the upper atmosphere (or stratosphere) (see also chlorofluorocarbons).

ozone layer

the zone of the upper atmosphere of about 15–30 km above the Earth (i.e. the lower stratosphere) where a comparatively high concentration of ozone is present. The ozone absorbs ultraviolet radiation from the Sun, so preventing excessive amounts from reaching the Earth.

polymers

large molecules consisting of repeated structural units; plastics.

precautionary principle

the assumption that any action which might cause environmental change, for example the release of a substance into the environment, is environmentally damaging until proved otherwise.

species

in the classification of living organisms, it is the smallest unit of classification commonly used; for the majority of plants and animals it is a group of individuals able to breed among themselves but not able to breed with organisms of other groups.

stratosphere

the layer of the atmosphere above the lower atmosphere, or troposphere, where our weather occurs. Its height varies with season and latitude, but usually lies between 10–15 km and 60–80 km above the Earth's surface.

sulphur dioxide

sometimes referred to as SO_2 or SO_x, an acid gas formed by the combustion of fuels containing sulphur (such as coal). Sulphur dioxide is responsible for acid rain which damages buildings and ecosystems and can cause localised respiratory problems.

sustainability

a concept that combines environmental impacts of human activities with social and economic concerns and relates to the capacity of the Earth to accommodate them (see also sustainable development).

sustainable development

a system of development that allows current generations to develop economically and socially without passing on insoluble problems to future generations. Often defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (see also sustainability).

toxicity

a measure of the potential damage to life posed by a particular substance or toxin. It is related to both concentration and time of exposure.

ultraviolet (UV) radiation

the energy radiating from the Sun with a wavelength shorter than visible light but longer than that of X-rays. The more energetic part of the UV radiation from the Sun is damaging to human and ecosystem health, but most of this is removed by the ozone layer before it reaches the Earth's surface.

value

a personal view of an issue or of the importance of taking or preventing a particular action. Values are subjective and cannot be described in tds of 'right and wrong'.

References

Blackmore, R. and Reddish, A. (eds.) (1996) Global Environmental Issues, Hodder & Stoughton in association with the Open University.

Blowers, A. (ed.) (1993) *Planning for a Sustainable Environment*, A report by the Town and Country Planning Association, London: Earthscan.

Brezet, J.C. and Van Hemel, C. (eds) (1997) *Ecodesign, a promising approach to sustainable production and consumption*, Paris: United Nations Environment Programme.

Brundtland, G.H. (chair), (1987) *Our Common Future*, The World Commission on Environment and Development, New York: Oxford University Press.

Carson, R. (1962) *Silent Spring*, Harmondsworth: Penguin, reprint 1991.

Chant, C. (ed.) (1989) *Science, Technology and Everyday Life 1870–1950*, London: Routledge in association with the Open University.

Department of Health, (1998) *Qualification of the Effects of Air Pollution on Health in the United Kingdom*, Committee on the Medical Effects of Air Pollutants, London: The Stationery Office.

Department of Trade and Industry (DTI) (1998) *Energy Sector Indicators 1998*, London: DTI.

Department of Trade and Industry (2004) Digest of UK Energy Statistics, online http://www.dti.gov.uk/energy/inform/ (accessed November 2004)

Energy and Environment Programme, Environmental Change Unit (ECU) (1997) DECADE *Transforming the UK Cold Market*, University of Oxford.

Furnival, J. (1998) *Suck, Don't Blow, The Gripping Story of the Vacuum Cleaner and other Labour Saving Machines around the House*, London: Michael O'Mara.

Heldman, D.R. and Hartel, R.W. (1997) *Principles of Food Processing*, New York: Chapman and Hall.

Hobsbawm, E.J. (1969) *The Pelican Economic History of Britain*, Volume 3, *Industry and Empire*, Harmondsworth: Penguin.

Jackson, T. (1996) *Material Concerns: pollution, profit and quality of life*, London: Routledge. [See especially the chapter on 'The Birth of the Industrial Revolution'.]

Met Office & DETR (1998) *Climate Change and its Impacts: some highlights from the on-going UK research programme*, London: Department of the Environment, Transport and the Regions.

Ochert, A. (1999) A warm weather warning, *The Times Higher*, 22nd January 1999.

Office for National Statistics (ONS) (1998) *Living in Britain: Results from the 1996 General Household Survey*, Table 3.20, Consumer durables, central heating and cars:1972 to 1996, London: The Stationery Office.

Taylor, R. (project leader) and Smith, I. (chief editor) (1997) *The State of New Zealand's Environment 1997*, Wellington: The Ministry for the Environment, New Zealand.

von Weisäcker, E. Lovins A. & Lovins L.H. (1997) *Factor Four, Doubling Wealth – Halving Resource Use*, London: Earthscan.

Wackernagel, M. & Rees, W. (1996) *Our Ecological Footprint*, British Columbia, Canada: New Society Publishers.

Acknowledgements

Cover image: CIAT in Flickr made available under
Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Licence.

Grateful acknowledgement is made to the following sources for permission to reproduce material in this text.

Figure 1 Wackernagel, M. and Rees, W. (1996) *Our Ecological Footprint*, New Society Publishers; *Figure 5*: © Greenpeace/Scharnberg;

Figure 6 Department of Trade and Industry (2004) Digest of UK Energy Statistics. Crown copyright material is reproduced with the permission of the Controller of HMSO; *Figure 7*: From *Decade*, 1995, Environmental Change Unit, University of Oxford; *Figure 8*: From *Decade*, 1997, Environmental Change Unit, University of Oxford.