

# esign + environment

HELEN LEWIS and JOHN GERTSAKIS, *RMIT University, Australia*  
with TIM GRANT and NICOLA MORELLI, *RMIT University, Australia*  
and ANDREW SWEATMAN, *Environmental and Occupational Risk Management, USA*

huge scarcity of good, practical resources for designers and students interested in minimising environmental impacts of products. *Design + Environment* has been specifically written to address this paucity.

The book first provides background information to help the reader understand how and why design for environment (DfE) has become so critical to design, with reference to some of the most influential designers and companies in the field. Next, *Design + Environment* provides a step-by-step guide on how to approach DfE: to design a product that meets requirements for quality, cost, reliability and consumer appeal, while at the same time minimising environmental impacts. Then the process is to undertake an assessment of environmental impacts, using life-cycle assessment (LCA) or one of the many simpler tools available to help the designer. From then on, DfE becomes an integral part of the normal design process, including the development of concepts, design decisions, final design and development of marketing strategies.

Environmental assessment tools and strategies to reduce environmental impacts, such as the selection of appropriate materials, are then discussed. Next, some of the links between environmental issues such as global warming, ozone depletion, water and air pollution and the everyday products that we use are considered. In order to design products with minimal environmental impact, we need a basic understanding of these impacts and the interactions between them.

The subsequent chapters provide more detailed strategies and case studies for particular product categories: packaging, textiles, furniture, and electrical and electronic products. Guidelines are provided for the critical stages of a product's life, from the selection of raw materials through to strategies for production and recycling.

*Design + Environment* takes a look at some of the emerging trends in DfE that are offering the opportunity to make a more significant reduction in environmental impacts. Both the development of more sustainable materials and technologies and the growing interest in leasing rather than owning products are examined.

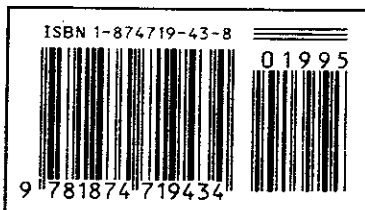
*Design + Environment* is organised as a workbook rather than an academic text. It should be read and then used as a key reference source. This clear and informative book will prove to be invaluable to designers, to course directors and their students in need of a core teaching and learning text and to all those interested in learning about the tools and trends influencing green product development.

The authors have all been involved in an innovative demonstration programme, 'EcoReDesign™', which is funded by the Centre for Design at RMIT University with funding from the Australian government. The programme has successfully collaborated with Australian companies to improve the environmental performance of their products by following DfE principles.

## Greenleaf Publishing

Aizlewood Business Centre, Aizlewood's Mill  
Nursery Street, Sheffield S3 8GG, UK  
Tel: +44 (0)114 282 3475  
Fax: +44 (0)114 282 3476  
E-mail: [sales@greenleaf-publishing.com](mailto:sales@greenleaf-publishing.com)

[www.greenleaf-publishing.com](http://www.greenleaf-publishing.com)



design + environment

# design + environment

a global guide to designing greener goods

HELEN LEWIS and JOHN GERTSAKIS

with TIM GRANT, NICOLA MORELLI and ANDREW SWEATMAN

## 5

THE ECOLOGY  
OF PRODUCTS

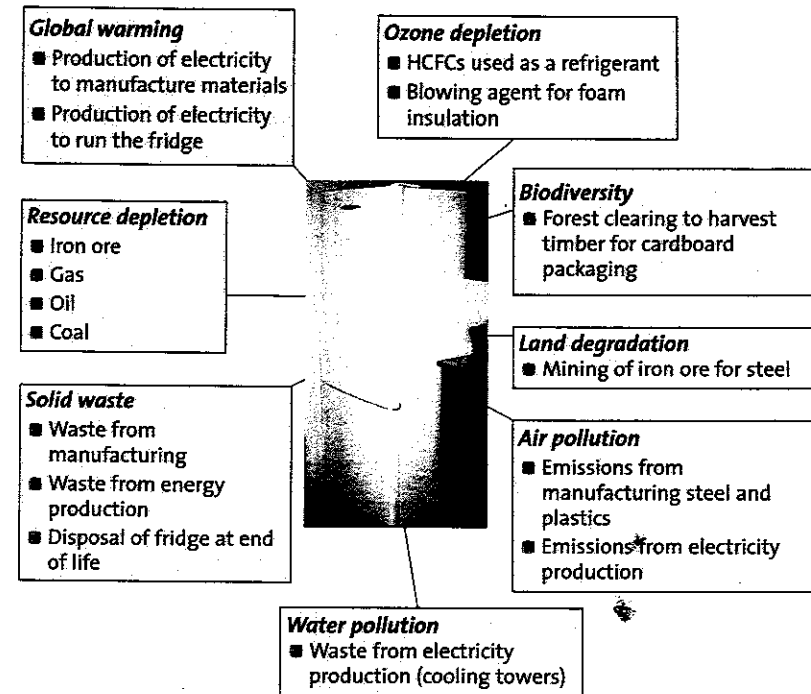
## 5.1 The ecological footprint

Every product we make and use contributes to environmental degradation in many different ways. It has an 'ecological footprint' that extends well beyond national boundaries and long after a product has been used and discarded. There are many tools available to help the designer assess the environmental impacts of a product, including life-cycle assessment (LCA) and eco-indicators. These are discussed in Chapter 3. The aim of this chapter is to introduce some of the major environmental problems and their links to product design. These problems are:

- Global warming
- Ozone depletion
- Reduced biodiversity
- Resource depletion
- Water pollution
- Air pollution
- Land degradation
- Solid waste
- Acidification

The importance placed on these environmental impacts varies between countries. Acidification, for example, is regarded as a bigger problem in Europe than it is in Australia, where land degradation issues such as deforestation and salinity are having a much greater impact.

The manufacture, use and disposal of each product contributes to environmental damage in a variety of ways. This is illustrated in Figure 5.1, which shows some of the links between a refrigerator and the environment.



HCFCs = hydrofluorocarbons

Figure 5.1 Environmental impacts of a refrigerator

It is important to remember that, when evaluating the environmental impacts of a product or design feature, every impact needs to be multiplied by the number of units manufactured or currently in use. A single appliance may have a negligible impact on the environment, but a million appliances do not. Similarly, a small design improvement may seem trivial until the environmental benefits are calculated and multiplied by the number of units in production.

## 5.2 Global warming

Evidence suggests the temperature of the Earth is gradually increasing as a result of the enhanced 'greenhouse effect'. The greenhouse effect is caused naturally by the accumulation of carbon dioxide (CO<sub>2</sub>) and water vapour in the upper atmosphere, which insulates the Earth and prevents heat loss. This effect appears to be accelerating as a result of emissions of CO<sub>2</sub>, methane, chlorofluorocarbons (CFCs) and nitrogen oxides (NO<sub>x</sub>) arising from human activity. The likely impacts of an

increase in global temperatures include rising sea levels and increasing rain and snowfall.

An international agreement to reduce global warming, known as the Kyoto Protocol, was signed in Japan in late 1997. Under this agreement most developed countries are committed to reducing their greenhouse gas emissions to 1990 levels and then to reduce them a further 5% by 2012. Australia and Norway will be allowed to increase their emissions on 1990 levels, but with a significant reduction on previous rates of growth.

One of the major sources of greenhouse gas emissions is the burning of fossil fuels such as coal, oil and gas to produce energy. Greenhouse impacts are therefore particularly relevant to appliances that consume energy during their life, such as water and space heaters, stoves and refrigerators. The choice of fuel is particularly important, with large differences in greenhouse gas generation between alternatives such as gas and electricity (see Fig. 5.2).

Wood	0.00
Natural gas	0.31
Liquified petroleum gas	0.34
Heating oil	0.39
Coke or briquettes	0.55
Electricity (Australian average)	1.00

Note: It is assumed that fuel burns at 70% efficiency; transport of wood, and land clearing for timber harvesting, generate greenhouse gas emissions not included here.

Figure 5.2 Kilograms of greenhouse gas generated per unit of heat delivered

Source: Pears 1997: 20

Design can also have a significant impact on greenhouse gas emissions related to a single product; for example, Figure 5.3 shows the variation in greenhouse gas emissions from a variety of appliances used to boil water for hot drinks. If we all shifted to use the most energy-efficient products currently on the market, domestic energy consumption could be reduced by around 75% (Aplin *et al.* 1999).

## 5.3 Ozone depletion

Ozone is a form of oxygen (O<sub>3</sub>) that forms a layer in the atmosphere between 20 km and 50 km above the surface of the Earth. The ozone layer protects us

3.2	Large boiling water unit
1.2	Large boiling unit with timer (10 h working day)
1.0	Small boiling water unit (24 h)
0.5	Small boiling water unit with timer (10 h working day)
3.3	Large urn (no thermostat, 10 h working day)
1.0	Small thermostatically controlled plastic urn (10 h working day)
0.4	Small drink dispenser (10 h working day)
0.4	Electric kettle

Figure 5.3 Annual greenhouse gas emissions of ways of supplying hot water for drinks (tonnes carbon dioxide per year, 60 cups per working day for a year)

Source: Sustainable Solutions 1993

against the harmful effects of the sun's radiation. Ozone is destroyed by reaction with nitric acid (created by the burning of fossil fuels) or chlorine compounds (e.g. CFCs used in refrigeration or foams).

Ozone-depleting substances are being phased out under an international agreement called the Montreal Protocol (see Table 5.1). These chemicals have traditionally been used as propellants, refrigerants and blowing agents. Recent evidence suggests that bromine-based chemicals are also damaging the ozone layer, but are not covered by the Protocol (Aplin *et al.* 1999).

## 5.4 Reduced biodiversity

Biodiversity is reduced when the number of plant and animal species is reduced at a local, regional or global level. This can occur for a number of reasons, for example:

- Land clearing for urban development, mining or other human activities
- Timber harvesting or clear-felling in old growth forests
- Pollution of air, soils or waterways

Tropical rainforests are among the most biologically diverse habitats (e.g. they are home to at least half the world's plant species). They are also experiencing extreme rates of species extinction (Aplin *et al.* 1999).

Ozone-depleting substances	Developed countries	Developing countries
Chlorofluorocarbons (CFCs)	Phased out end of 1995	Total phase-out by 2010
Halons	Phased out end of 1993	Total phase-out by 2010
Carbon tetrachloride	Phased out end of 1995	Total phase-out by 2010
Methyl chloroform	Phased out end of 1995	Total phase-out by 2015
Hydrochlorofluorocarbons (HCFCs)	Freeze from beginning of 1996 35% reduction by 2004 65% reduction by 2010 90% reduction by 2015 Total phase-out by 2020	Freeze in 2016 at 2015 base level Total phase-out by 2040
Hydrobromofluorocarbons (HBFCs)	Phased out end of 1995	Phased out end of 1995
Methyl bromide	Freeze in 1995 at 1991 base level 25% reduction by 2001 50% reduction by 2005 Total phase-out by 2010	Freeze in 2002 at average 1995-98 base level

Table 5.1 Summary of Montreal Protocol control measures

Source: CEPA 1996

Scientists and policy-makers are still grappling with complex issues relating to how we measure and protect biodiversity in the environment. Designers need to be aware that any product made or derived from biological resources, such as timber, may have implications for biodiversity. Impacts can be minimised through careful selection of materials (e.g. timber certified by the Forest Stewardship Council [FSC]), design for material efficiency and use of recycled materials and by-products.

## 5.5 Resource depletion

Many of the raw materials we use are non-renewable, and supplies are limited. In 1972 a report to the Club of Rome warned of dire consequences to humankind unless exponential growth in population and consumption could be controlled:

If the present growth trends in world population, industrialisation, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable results will be a rather sudden and uncontrollable decline in both population and industrial capacity (Meadows *et al.* 1972: 23).

On a positive note, we are starting to see a change in the relationship between industrial growth and consumption of energy and raw materials. The World Commission on Environment and Development (WCED 1987) noted that, while growth has continued in developed market economies, the demand for many basic raw materials has levelled off or declined. Energy consumption per unit of gross domestic product (GDP) in countries in the Organisation for Economic Co-operation and Development (OECD) has been dropping at a rate of 1%–3% every year since the late 1960s. Between 1973 and 1983, energy efficiency improved in OECD countries by 1.7% annually.

This is a positive trend, but there is no room for complacency. World population is increasing at a rate of almost 100 million people per year and is expected to reach 10,000 million by 2050. Developing countries account for 95% of the increase, but every additional citizen in the USA adds statistically more stress to the natural environment than 20 citizens in India or Bangladesh (von Weizsäcker *et al.* 1997).

Resource conservation should be considered in the design, manufacture, use and disposal of every product. Materials need to be used efficiently and recovered at the end of their life for recycling. In their book, *Factor Four: Doubling Wealth, Halving Resource Use*, Ernst von Weizsäcker, Amory Lovins and Hunter Lovins argue that we can use resources at least four times more efficiently than we do now, without compromising our quality of life, and the authors provide numerous examples to support their claim (von Weizsäcker *et al.* 1997).

## 5.6 Water pollution

The most common sources of water pollution are discharges from industrial processes, household sewerage, storm-water drains and run-off from agriculture. Waterborne wastes from industrial processes may include trace metals, nutrients, solvents, oils, organic substances, acids and suspended solids (see Table 5.2).

Water pollution can have a visual impact, but it can also be hazardous or toxic to aquatic life. Suspended solids in water reduce water clarity, and turbid waters are poor habitats for fish and other aquatic life. Trace metals can be toxic to aquatic life and can bioaccumulate in the food chain.

Industries contributing to waterborne emissions of trace metals include electroplating, leather tanning, the use of heavy metals in printing inks (although this is declining significantly as alternatives become available) and the use of batteries with high concentrations of heavy metals. Solvents are widely used in industry to remove scale, rust and other surface contaminants from metals.

Water pollution is also generated during the use of some appliances (e.g. detergents in waste-water from washing machines and dishwashers). These impacts can be minimised through use of biodegradable detergents or through better design of the appliance to minimise water use.

Process	Trace metals	Nutrients	Solvents, oils	Organic substances	Acids	Suspended solids
Agriculture	n/a	●●●	n/a	●●●	n/a	●●●
Chemical manufacture	●●	n/a	●	●	n/a	●●
Electronics	n/a	n/a	●	●●	n/a	n/a
Electroplating	●●●	n/a	●	n/a	n/a	●●
Fertiliser	n/a	●	n/a	n/a	n/a	●●
Food production	n/a	●●	n/a	n/a	n/a	n/a
Leather making	●●	n/a	n/a	●	n/a	n/a
Metal cleaning	n/a	n/a	●	●	n/a	●
Mining, smelting	n/a	n/a	n/a	n/a	●	●●●
Pesticides, herbicides	n/a	n/a	n/a	n/a	●	n/a

- Modest impact on local, regional or global scale
- Minor influence on local, regional or global scale
- Major influence on local, regional or global scale
- n/a Not applicable

Table 5.2 Waterborne wastes emitted by common industrial processes and products

Source: Graedel and Allenby 1995: 212

When products are disposed of to landfill they can generate water pollution by leaching metals or other toxic substances into ground-water.

## 5.7 Air pollution

Sources of air pollution include emissions from factories, power-generating plants, wood fires and motor vehicles. Typical pollutants include CO<sub>2</sub>, NO<sub>x</sub>, sulphur dioxide (SO<sub>2</sub>), ozone and volatile organic compounds (VOCs). The environmental impacts of air pollution include:

- Global warming (e.g. by CO<sub>2</sub>, methane)
- Ozone depletion (e.g. by CFCs)
- Acid rain (e.g. from SO<sub>2</sub>)
- Health impacts (e.g. from solid particles)

Air pollution has reduced significantly in many developed countries following the introduction of environmental regulations, emission controls and lead-free petrol. Since the mid-1980s the number of 'smog alert' days in Melbourne has dropped from about 100 per year to between 15 and 20. In many Australian cities, smoke from wood heaters and open fires has overtaken motor vehicles as the

major source of particle air pollution, which can cause a range of lung diseases in winter. Pollution from diesel engines is also a cause for concern because of the growing number of diesel-powered small commercial and four-wheel-drive vehicles (Strong 1998: 15).

Design can play a major role in reducing air emissions from vehicles. Between 1973 and 1986 the average car made in the USA became twice as efficient, from needing 17.8 litres fuel per 100 km to needing 8.7 litres fuel per 100 km. About 4% of the savings came from making cars smaller, and 96% from making them lighter and better (von Weizsäcker *et al.* 1997: 4-5). Increasing efficiency means less fuel is burned, resulting in lower air emissions. 'Ultralite' concept cars manufactured with strong, lightweight composite materials and a hybrid-electric drive instead of the conventional engine have the potential to reduce fuel use by 80%–95% and to cut 90%–99% of air emissions (von Weizsäcker *et al.* 1997: 10).

## 5.8 Land degradation

Land degradation concerns the adverse effects that various uses of land by humans have had on the environment. These effects include reduced soil fertility, soil erosion, salinity of land and water, weed invasion, removal of topsoil and deforestation.

The 'ecological footprint' of many products involves mining to generate energy and to extract mineral ores. This can require the movement of enormous quantities of soil and rock ('overburden') to get access to minerals, and large amounts of ore need to be crushed and processed to extract valuable metals. A gold ring weighing 10 g, for example, requires the mining and processing of 3 tonnes of ore (von Weizsäcker *et al.* 1997: 242).

Open-cast mining involves the removal of vegetation and causes disruption to local ecosystems. For this reason metals should always be used efficiently and recycled. Each tonne of recycled metal used in manufacturing eliminates the need to extract thousands of tonnes of ore.

## 5.9 Solid waste

Despite recent initiatives to expand recycling programmes and encourage source reduction, the amount of waste we throw away is still increasing. Between 1960 and 1997 the amount of waste thrown away per person in the USA increased by 45%. During the same period, materials recovery increased from 6.4% to 28% of total waste, but this was insufficient to counteract the increase in waste generation. The increase in waste generation has been attributed to increased economic activity and consumption levels (Franklin Associates 1999: 3-5).

Products generate solid waste in manufacture, use and disposal. Some of this waste is recycled, but most is disposed of in incinerators or landfills. Incinerators generate air pollution and toxic ash (which must also go to landfill), and landfills generate methane gas and waterborne pollutants that can pollute ground-water. Many of these pollutants can be traced back to everyday products (e.g. heavy metals in printing inks and old paint tins, lead oxide in television tubes and light bulbs, and cadmium in rechargeable batteries). Landfills also take up valuable land that could otherwise be used for urban development, agriculture or other higher-value uses.

It is no longer acceptable to manufacture products for single use (e.g. disposable packaging) or to design 'durable' appliances with in-built obsolescence. When products are thrown 'away', they do not just disappear—they sit in holes in the ground for hundreds or thousands of years.

Archaeological 'digs' in landfills have revealed the fact that biodegradation in modern landfills is very slow or non-existent. Well-known US 'garbologist' Dr William Rathje claims that, although some degradation of organic material does occur, 'well-designed and managed landfills seem to be far more apt to preserve their contents for posterity than to transform them into humus or mulch' (Rathje 1992: 112). He points out that:

Biodegradation works most efficiently under composting conditions, when debris is chopped up, regularly turned, kept wet and exposed to the oxygen that microorganisms, which biodegrade organic material in the most straightforward way, require. These conditions are not met in modern landfills. The garbage stays where it has been dumped, tightly compacted but largely intact (Rathje 1992: 117).

The implication for product designers is that choosing a biodegradable material such as paper or a starch-based plastic will not automatically eliminate waste. Unless the product is likely to end up in a compost facility or a bio-reactor landfill, it is still likely to remain intact in the ground for tens or hundreds of years.

The most common materials found in municipal waste (by weight) are paper and paperboard, organic materials such as garden trimmings and food, and plastics (see Table 5.3).

## 5.10 Acidification

'Acid rain' is caused mainly by sulphur dioxide, nitrogen oxides and other pollutants that are released into the atmosphere when fossil fuels such as oil or coal, which contain sulphur, are burned. Acid rain can be carried many kilometres in air currents before falling to the ground, which explains why Scandinavia receives acid rain from factories in Germany, and why Canada receives acid rain from factories in the USA. Acid rain kills wildlife and trees (Collins 1995: 3).

Once again, the imperative for the designer is to choose cleaner sources of energy (such as gas or solar energy) and to design for maximum efficiency.

<i>Material</i>	<i>Percentage of total municipal waste (by weight)</i>
Paper and paperboard	38.6
Yard trimmings	12.8
Food	10.1
Plastics	9.9
Metals	7.7
Glass	5.5
Rubber, leather, textiles	6.8
Wood	5.3
Other	3.3
<i>Total</i>	<i>100.0</i>

Table 5.3 Composition of domestic waste in the USA, 1997

Source: Franklin Associates 1999: 9

## Useful websites

### World Resources Institute (WRI)

[www.wri.org](http://www.wri.org)

The WRI claims to 'provide information, ideas and solutions to global environmental problems'. It publishes annual reports on the state of the environment (e.g. WRI 1998) and has an excellent website.

### United Nations Environment Programme (UNEP)

[www.unep.org/SGE/](http://www.unep.org/SGE/)

This website provides a summary of UNEP's first report on the global environment (UNEP 1997) as well as links to national and regional reports on the state of the environment.