Energy and the New Reality 1

# Energy Efficiency and the Demand for Energy Services

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# 11

# Policies to Reduce the Demand for Energy

In this, the concluding chapter of Volume 1, the policies and programmes needed to dramatically reduce the demand for energy relative to business-as-usual scenarios are briefly outlined. The demand for energy depends on the demand for energy services as well as the efficiency with which these services are provided. The demand for energy services in turn depends on the human population and the average GDP per person, with the particular mix of energy services demanded dependent on economic development, energy prices and lifestyle factors. All of these factors are addressed in this chapter. Policies and programmes to promote lower growth in the human population and in average GDP/person are outlined, as well as policies to dramatically reduce the energy intensity of the global economy. Dramatic improvements in energy efficiency can be largely achieved with existing technologies, but important areas for further research and development are identified here.

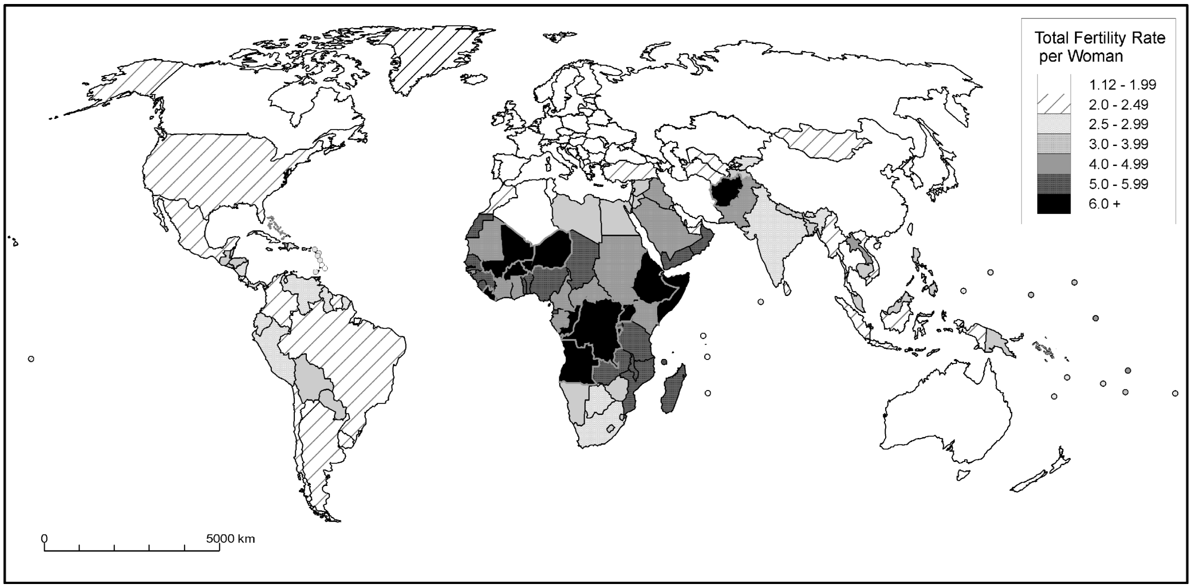
Energy savings achieved through improved energy efficiency, if unaccompanied by measures to limit overall demand for energy services, tend to be eroded by increased energy use elsewhere in the economy – a phenomenon referred to as the rebound effect. The issue of the rebound effect and the broader question of the links between human happiness, economic growth and sustainable levels of consumption are addressed here.

## 11.1 Limiting future population

The rate of growth of population depends on the difference between birth rates and death rates. Given the desirability of reducing death rates by increasing the average human lifespan, the key to limiting future increases in human population is to rapidly reduce birth rates or fertility – expressed as lifetime births per woman.[1] The replacement level of fertility is about 2.1 in developed countries and as high as 3.3 in some developing countries, with a global mean of about 2.3. The replacement level is greater than 2.0 due to differences in the male to female sex ratio (more males) at birth and due to mortality of some females before they reach the end of their fertility. Figure 11.1 shows fertility rates across the world. In all OECD countries except the US and in the former Soviet Union, China, Thailand, Vietnam, Iran, Tunisia, Algeria, Cuba, Brazil, Uruguay and Bolivia, fertility rates are now less than 2.0. However, fertility rates are still very high in most of Africa, in parts of Central America and the Caribbean, and in Paraguay. The relatively high fertility rate in the US (2.1) is due to high fertility among Hispanics and other minority groups and to a relatively high fertility among non-Hispanic white people (1.9, compared to 1.3–1.8 in Western Europe). In most countries with sub-replacement levels of fertility, population is still growing because the age structure is such that death rates are still less than birth rates.

Nearly one billion people live in countries in which fertility averages four or more children per women, such that the population would double with current growth rates in less than 35 years (Leahy et al, 2007).[2] It is widely recognized that the keys to limiting fertility rates where they are still high are:

- to reduce the demand for large families by making it socially and economically advantageous to have fewer children;




*Source:* Data from US Census Bureau (www.census.gov/ipc/www)

**Figure 11.1** *Fertility rates in the countries of the world*

- to increase the educational level of women so that marriage is delayed and women have alternatives to a life with many children (according to Birdsall (1994) each additional year of female education reduces fertility by 5–10 per cent);
- to provide family planning and contraceptive services so that unwanted pregnancies can be avoided (according to Bongaarts et al, (1997) one in five births in the mid-1990s were unwanted and 25 million abortions were performed annually due to insufficient access to contraceptives).

Two of the keys to reducing the demand for large families are (1) to provide old-age security, and (2) to provide economic incentives of various sorts. The demand for large families decreases on its own with urbanization because extra children become an economic burden rather than an economic asset.

China, Iran, Mexico and Tunisia all provide examples of rapid declines in fertility rate (Leahy et al, 2007). In 1979, China introduced a policy of encouraging (through financial incentives but also sometimes through coercive measures) only one child per family. Chinese fertility rates fell from around 5 children per women in 1970 to an estimated 1.3–2.0 (probably 1.6–1.8) today, with most of the decline occurring before implementation of the one-child policy (the one-child policy is nevertheless credited with avoiding 300–400 million births up to the present).

In the case of Iran, a national family planning programme was fully implemented in the early 1990s. It involved modern free contraceptives on demand at clinics and mandatory attendance by prospective married couples at a government-sponsored class on family planning prior to receiving a marriage licence. Fertility rate fell from 6.5 children per women in 1980 to 1.71 children per woman by 2007. Iran's population growth rate dropped from an all-time high of 3.2 per cent/year in 1986 to 1.2 per cent/year in 2001 and 0.7 per cent/year in 2007 (due in part to a net out-migration of 4.29/1000/year). The Iranian experience indicates that economic growth is not a prerequisite to large declines in fertility. Mexico also saw a sharp decline in fertility following the introduction of a national family planning programme (in 1972) and later improvements in health services, falling from 6.5 children per women in the early 1970s to 2.15 by 2005. A third example is Tunisia, where fertility fell from more than seven children per women in 1960 to two children per woman by 2005.

Apart from limiting future GHG emissions (and other impacts of humans on the environment) by reducing the future human population, family planning services will improve the health of mothers and those children that are born, and will reduce the dilution of increased services (as the economy grows) among a growing population. A smaller future population will also limit the impact of adverse climatic change in the future and, indeed, will reduce the number of people at risk of hunger even in the absence of climatic change (as discussed by Smil, 1994b, the world agricultural system is likely to be able to feed a world of 9 billion people, but will be hard pressed to feed a substantially larger population, although a sufficient moderation in projected future meat consumption could compensate for an increasing population and adverse climatic change). A decline in fertility rates through an increased supply of condoms will also do much to reduce the spread of HIV/AIDS, which is a particular problem in some of the very countries (in Africa) with the highest fertility rates.

## 11.2 Limiting economic growth

Stabilization of climate will ultimately require constraints on economic growth (if such constraints do not arise naturally as a result of shortages of materials and cheap energy), that is, in the consumption of goods and services. If per capita consumption of goods and service were to continue to grow exponentially indefinitely, such growth would ultimately swamp the gains that are possible through improved energy efficiency and overwhelm the earth's ability to provide renewable (carbon-free) energy on a sustainable basis.

In this section, three strategies for limiting economic growth in wealthy countries are briefly discussed. These are:

1 to shift attention and policy goals away from maximization of GDP and toward maximization of broader indicators of human happiness;
2 to promote shorter working hours or at least greater choice in the number of hours worked; and
3 to promote greater product longevity.

### 11.2.1 Limiting economic growth by focusing on determinants of human happiness

GDP per capita has been used as a proxy for human happiness, but growth in GDP has become a goal in and of itself. However, there is growing evidence that, beyond some level of GDP per person, increasing GDP per capita does not increase human happiness and, in many cases, leads to decreased happiness. At any given point in time, individuals with higher income tend to rate themselves as happier than do individuals with lower income, but over time, there has been almost no increase in reported happiness within a given country, and in some cases a decrease, as incomes have increased (Frey and Stutzer, 2002). The fundamental reason why increased consumption does not lead to an increase in happiness is that the happiness associated with consumption largely depends on one's wealth *relative* to other people (Layard, 2003, 2005). Since it is impossible to simultaneously make everyone wealthier relative to everyone else, it is impossible to increase overall happiness by pursing greater GDP per person, yet such pursuit is a prime driver of environmental destruction and increasing GHG emissions. It is thus important to long-term climate stabilization to be able to direct current thinking in society away from the belief that increasing consumption is a source of happiness.

In order to do this, it is necessary to recognize the different kinds of human needs that are satisfied, to varying degrees, by material consumption. As discussed by Maslow (1954), Max-Neef (1992), Michaelis (2003) and Hofstetter et al (2006), among others, these needs include physiological needs (food, clothing, shelter) but also a wide range of non-physiological needs such as social recognition, self-esteem, affection, cultural expression and self-actualization. To achieve sustainable and climate-friendly levels of consumption requires encouraging the production of goods and services that maximize the satisfaction of human needs while minimizing the use of materials and energy. For example, a shift in urban development toward more compact forms that require less time for commuting, and investment in high-quality rail-based rapid-transit infrastructure that ultimately costs less than car-based transportation systems (including the purchase and operating costs of cars) can free up more time to be spent with one's family or for creative leisure activities, both because less time is required for commuting and also because less hours need to be worked due to the reduced expenses if one can forego the purchase of a personal automobile altogether.

Jackson (2009) calls for increasing the means for people to flourish (physically, psychologically and socially) in less materialistic ways so that they are less dependent on their display of consumption as a means of broadcasting their social status. He suggests that a core element of this will include reducing social inequality by reducing huge income disparities – reining in the salaries that excessively reward socially detrimental behaviour while providing better salaries for – and thus better recognition of – those engaged in child care and care for the elderly and disabled. Daly (1996) also argues that a less unequal distribution of income (through maximum as well as minimum income) is a prerequisite for limiting the endless growth in consumption.

To achieve sustainable and climate-friendly levels of consumption also requires educating the public (beginning with the primary education system) into greater reflection on the sources of long-lasting happiness. Kasser (2002), in *The High Price of Materialism*, notes that setting and achieving non-materialistic goals brings a greater sense of well-being than setting and achieving materialistic goals, while Diener and Oishi (2000) find that those valuing love higher than money have a much higher life satisfaction than those who give priority to money. As discussed by Schwartz (2004), excessive choice in what is available for purchase also tends to a decrease happiness and satisfaction with what we do buy (more choices require more time for decision-making, more reasons for regret and more opportunities for people to judge their condition unfavourably by comparisons with others), which in turn fuels more consumption that never makes people as happy as they expected. (At the personal level, Schwartz provides a number of suggestions to avoid becoming a victim of excessive choice.)

Michaelis (2003) recommends the following strategies to reduce consumption:

- promoting diversity and understanding the thinking of those with 'ethical consumption' so that governments can develop effective arguments and stimuli for reduced consumption as part of a public dialogue;
- supporting groups such as Simplicity Circles (discussed by Maniates, 2002), the growing Transition Town initiative (see www.transitiontowns.org) and community EcoTeams, as it is usually difficult for individuals to change consumption patterns unless they belong to a supportive group that affirms their values and beliefs;
- applying the ideas used to promote technological innovation to social innovation, especially supporting new emerging practices;
- promoting and using alternative indicators of 'progress' (rather than just GDP);
- shifting employment law and taxation in order to promote more leisure time.

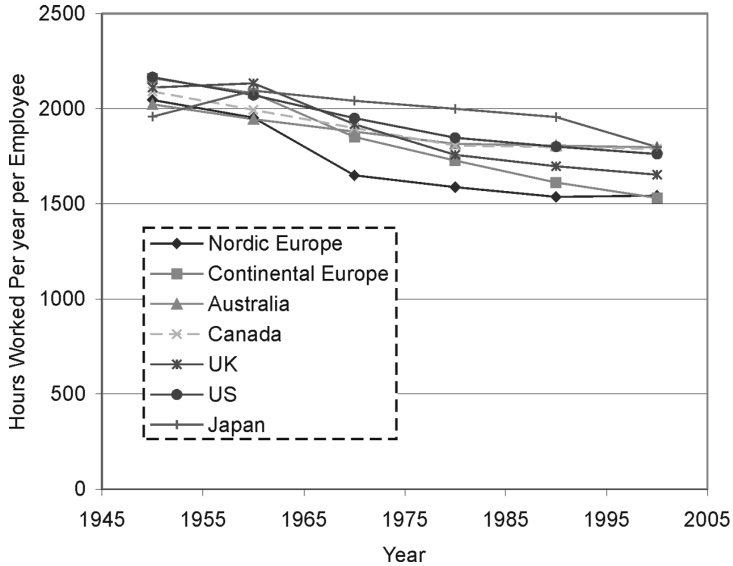
Marketing, however, constitutes a formidable force encouraging ever more consumption, permeating every element of most people's day-to-day lives. Restrictions on marketing could therefore be quite effective but are difficult to implement. Some countries have tried to limit advertising to children, with mixed success, but in any case they cannot control satellite TV. Increasing public funding of schools and universities to the level needed for them to provide the expected services, so that they are not partly dependent on advertising revenue, could reverse the invasion of marketing into the realm of public education, and government support (or greater government support) for public broadcasting could at least provide the public with television and radio free of advertising.

The following paragraphs focus on ways of promoting shorter working hours and more leisure time.

### 11.2.2 Limiting economic growth through reduced working hours

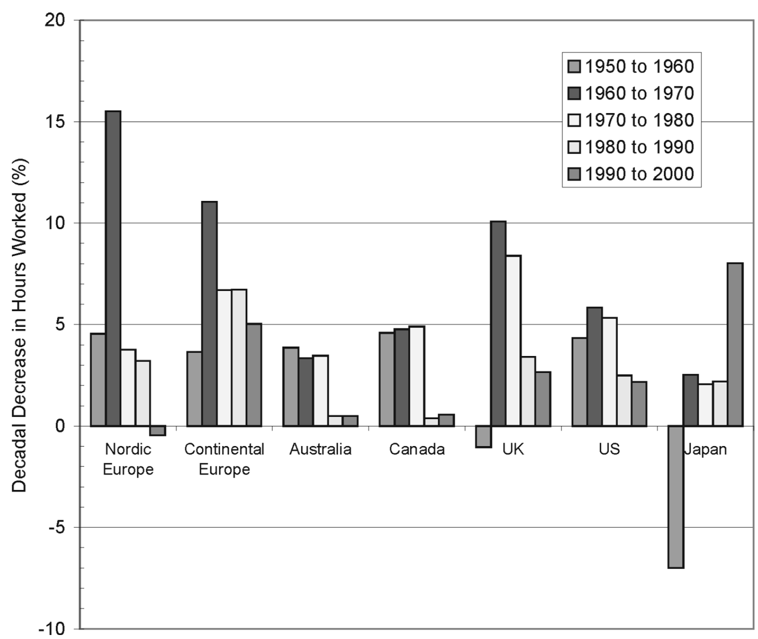
A shift toward shorter working hours will reduce the income available to spend on energy-consuming goods and services. As discussed by Schor (2005), annual hours worked in the US and Britain rose to a peak in the mid-19th century, then began a long decline until the 1980s. Figure 11.2 gives the variation in the number of hours worked per year per employee in European countries, Australia, Canada, the US and Japan from 1950 to 2000, while Figure 11.3 gives the percentage decrease by decade and Figure 11.4 gives the overall decrease from 1950 to 2000. In most countries, decadal decreases of about 5 per cent occurred from 1950 to 1980, but during the last two decades there has been a much smaller or no decrease, with the exception of Japan (which still has the highest number of hours worked per employee).

Resistance to shorter working hours comes both from employers and sometimes from employees. As discussed by Schor (2005), firms tend to resist a



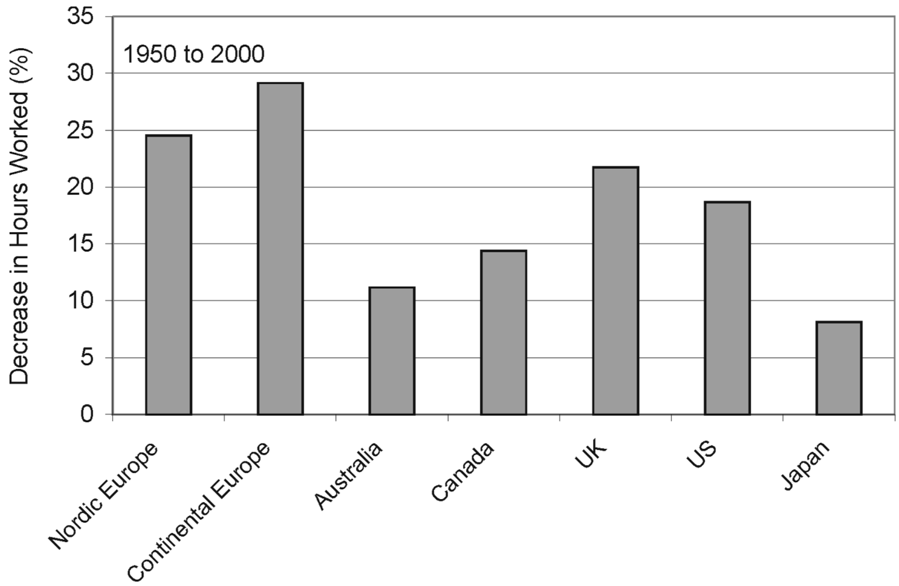

*Source:* data from Schor (2005)

**Figure 11.2** *Variation in the number of hours worked per year per employee in European countries, Australia, Canada, the US and Japan from 1950 to 2000*




*Source:* Computed from data in Schor (2005)

**Figure 11.3** *Percentage decrease by decade in the number of hours worked per year per employee in European countries, Australia, Canada, the US and Japan from 1950 to 2000*




*Source:* Computed from data in Schor (2005)

**Figure 11.4** *Overall decrease from 1950 to 2000 in the number of hours worked per year per employee in European countries, Australia, Canada, the US and Japan*

reduction in the number of working hours per employee compensated by an increase in the number of employees for several reasons. Foremost among these is the fact that employment-related costs (such as employer contributions to health care or disability insurance) tend to be structured on a per-person basis rather than on a per-hour basis (even when these costs vary with hours worked, they tend to be capped at a certain level, introducing a per-person rather than a per-hour component if the cap is sufficiently low that those with reduced working hours still reach it). Thus, greater public financing of costs such as health care and disability insurance will reduce the pressure to maintain the current number of working hours per employee. Schor (2005) argues that there is not a real 'market' in number of hours worked; that is, that current numbers of hours worked do not reflect workers' preferences concerning the balance between income and leisure time. In countries where unions are stronger, the creation of a market in hours worked is easier because unions can bargain for workers as a whole. Some employees will of course prefer to maintain current numbers of working hours (and pay levels) because of the high cost (for them) of day-to-day living.

A number of strategies have been suggested to make it easier for workers to choose to work less, but not all of these will necessarily be accompanied by a reduction in material consumption, which is the motive here.[3] The strategy most likely to increase the preference of employees for shorter working hours is to gradually restructure society so as to reduce the cost of day-to-day living. This would include measures to encourage the provision of more affordable housing (such as smaller housing with more efficient use of space, as discussed in Chapter 4, subsection 4.2.7) and provision of sufficiently good public transportation alternatives to travel by automobile, so that foregoing the purchase of an automobile becomes a viable option for a larger segment of the population. These strategies will also directly reduce energy consumption.

Finally, Schor (2005) suggests that as the economy shifts to more leisure time, there will be less demand for speed and convenience. As many of the devices that provide speed and convenience are energy intensive, this would be equivalent to a negative rebound on energy use (that is, an initial measure to reduce energy use (reduced working hours) leads to further reductions in energy use, rather than eroding the initial savings in energy use).

A gradual reduction in consumer spending would not lead to a noticeable increase in unemployment if it is brought about by working less. If, over time, there is a societal shift to less emphasis on material consumption as a source of happiness, there would presumably be a desire to work less on average, so the need for work could be redistributed among more people. The result would be lower economic growth (that is the intention), but also, more free time, less stress, less useless and counterproductive material consumption and less waste.

### 11.2.3 Limiting economic growth through a focus on product longevity

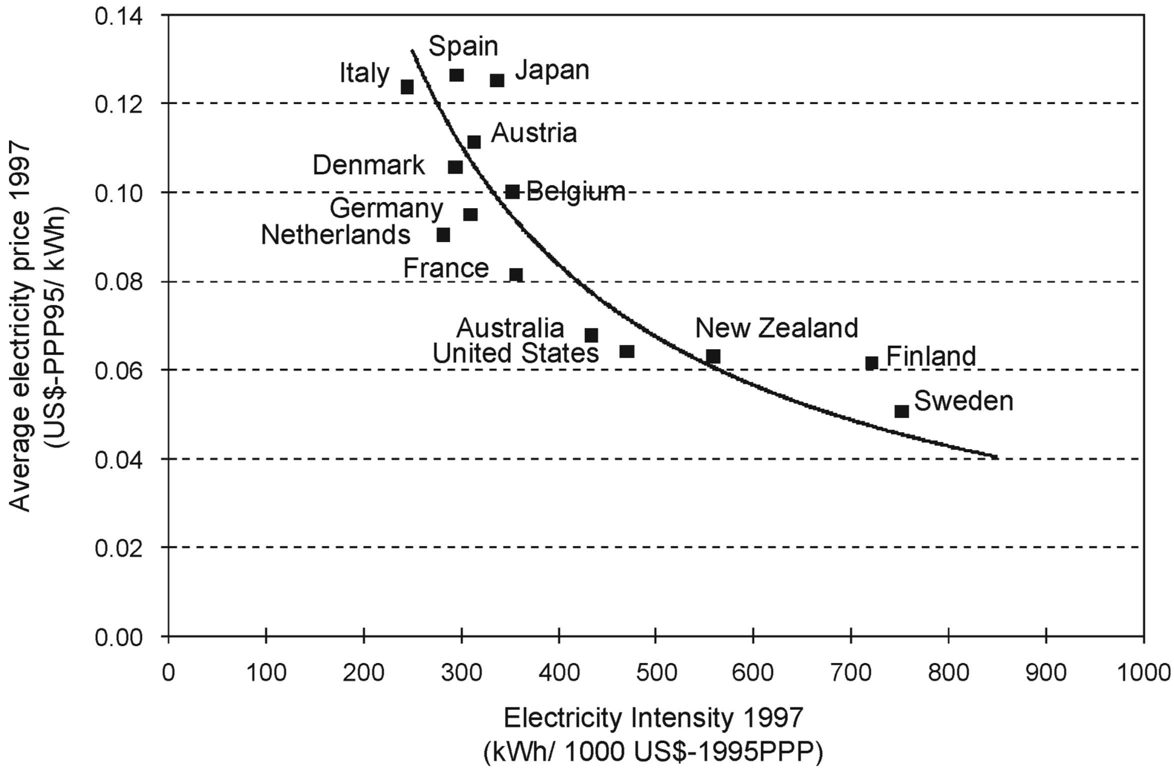
As pointed out by former World Bank economist Herman Daly, GDP is largely a measure of the *throughput* of material goods and energy in the economy, rather than a measure of the physical stock of assets that can be used and enjoyed (Daly, 1996). The faster these assets wear out, the harder we have to work – the greater the GDP – in order to maintain a given quantity of assets. If assets were to last longer, they would not have to be replaced as often and, depending on the effort required (and hence cost) to make longer-lasting goods, we would not have to work as hard. GDP would fall but there would be no reduction in what matters (the stock of assets) while life would be better because we would have more leisure time and less stress. In many instances, goods are discarded not because they have worn out, but because we have grown tired of them or they have gone out of 'fashion'. For example, according to studies cited by Cooper (2005), one third of discarded appliances in the UK are still functional and another third could be repaired, while 77 per cent of discarded upholstered furniture could theoretically be refurbished and reused.

A factor that has led to a decrease in repairing of broken items in countries such as the UK or the US is that repair work is done using high-cost local labour, whereas manufacturing is done on a large scale elsewhere using low-cost labour. The relocation of manufacturing to low-income countries may also have led to a loss of workers skilled enough to be employed in repair shops. To increase the lifespan of consumer products, there must be a greater emphasis on designing products for longevity, quality and greater ease of repair, and there must be a shift in consumer attitudes. Increased quality of course increases longevity because the product will need repair less frequently and also because purchasing a new high-quality product is more expensive than purchasing a mass-produced replacement, so it is more worthwhile to repair the product. Ax (2001), for example, argues that handcrafted shoes are more likely to be repaired because they are more comfortable and attractive than cheap, mass-produced shoes (which are also inherently difficult to repair). Owners of products will need to develop greater attachment to their possessions, rather than aspiring to update them as soon as new models appear on the market (Cooper, 2005).

## 11.3 Increasing the price of energy

An important underlying strategy in reducing GHG emissions is to provide a steadily increasing carbon tax that is applied, without exception, to all sources of energy in proportion to their $CO_2$ emission. The revenues from such a tax can be used to reduce other taxes (such as payroll taxes), to support energy efficiency measures, and to blunt the hardship otherwise imposed on low-income people. Although C-free sources of energy would not be taxed, these energy sources are in general more expensive than fossil fuels. By increasing the cost of fossil fuels to the point where C-free energy sources are competitive, the overall cost of energy will increase and the demand for energy will decrease. Taxing $CO_2$ emissions is preferable to subsidizing C-free energy sources because subsidization encourages more consumption than if all costs reflected true costs, and so leads to greater overall costs to society (as well as burdening government finances).[4]

The fundamental importance of high energy costs in reducing long-term energy demand is illustrated in Figure 11.5, which shows the relationship between the cost of electricity and the electricity intensity of the economies of wealthy OECD countries. A factor of two greater cost of electricity is roughly associated with a factor of two smaller electricity intensity. This is due in




*Source:* Verbruggen (2006)

**Figure 11.5** *Relationship between electricity price and electricity intensity in selected wealthy OECD countries*

part to the decision to locate electricity-intensive industries (such as aluminium smelting) in countries with low electricity costs, with export of electricity-intensive products to countries with higher electricity costs, but this is likely to be a small factor. Rather, as stated by Verbrugeen (2006), one cannot bypass an increase in electricity prices in raising the overall electricity efficiency of a country. High energy costs work to reduce energy demand in two ways: by changing consumer behaviour and purchasing decisions, and by promoting innovations that lead to more energy-efficient equipment.

However, an increase in the cost of energy alone is a crude instrument, imposing unnecessary hardship on some people, sectors and regions and being relatively ineffective if not accompanied by a wide array of supporting measures. Verbruggen (2006) draws an interesting analogy with heat engines: the fundamental limitation in the efficiency of a heat engine is given by the Carnot Cycle efficiency, which depends on the difference between the input and output temperatures (see Equation (3.16)). Because the minimum output temperature is limited by the ambient temperature, the limit on the efficiency of a heat engine is determined by the temperature of the hot source. The actual efficiency of the heat engine depends on the layout and performance of the machinery in extracting work from the heat flow between the hot source and cold sink. However, even the best-performing machinery cannot provide a high conversion efficiency if the driving temperature difference is small. Similarly, when energy costs are low, there is not enough financial pressure to induce changes, but a well-designed policy apparatus is needed to effectively convert the driving force into real change. In the following sections, we consider elements of well-designed policy packages for promoting energy efficiency.

## 11.4 Promoting energy efficiency

Across-the-board increases in energy efficiency, both at the scale of individual energy-using devices (for example, boilers and automobiles) and systems (for example, building thermal envelopes and transportation infrastructure) are needed. Extensive discussions of policy options can be found in Geller (2004), Geller et al (2004) and Gillingham et al (2006), as well as in the various chapters of the report of Working Group III of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (see, in particular, Sims et al (2007) with regard to electricity supply, Ribeiro et al (2007) with regard to transportation, Levine et al (2007) with regard to buildings and Bernstein et al (2007) with regard to industry). Some key elements of effective energy-efficiency policies in different sectors are outlined here.

### 11.4.1 Buildings and district energy systems

Chapter 4 of this book explained how deep (factors of three to five) reductions in the energy requirements of new buildings can be achieved, compared to current designs, and how factors of two to three (and sometimes much more) reduction in the energy use of existing buildings can be achieved. A more thorough discussion of how to achieve such large energy savings is found in Harvey (2006).

The primary barriers to achieving deep reductions in energy use in new buildings are not technological (because technologies and, more so, system designs, already exist that can provide deep reductions) nor even economic (because fully integrated designs entail very little and often no additional upfront cost compared to current conventional practice, as extensively documented earlier in this book). Rather, the barriers are behavioural in nature: they involve the fragmented nature of the design process and resulting lack of optimization, lack of awareness, time constraints during the design process, and an over-reliance on established ways of doing things. There is a widespread if not universal perception that low-energy buildings must, *of necessity*, entail greater capital costs. This leads to a lack of desire on the part of the client to have a low-energy building, and without a committed client, architects and engineers will usually not undertake the additional design effort required to produce low-energy buildings.

Lack of awareness of energy-savings opportunities among practising architects, engineers, lighting specialists and interior designers is a major impediment to the construction of low-energy buildings. This in part is a reflection of inadequate training at universities and technical schools, where the curricula often reflect the fragmentation seen in the building design profession. There is a significant need, in many countries, to create comprehensive, integrated programmes at universities for training future architects and engineers in the design of low-energy buildings, with parallel programmes at technical schools for training technical specialists. The value of such programmes would be significantly enhanced if they have an outreach component to upgrade the skills and knowledge of practising architects and engineers and to assist in the use of computer simulation tools as part of the integrated design process.

Significant reductions in energy use (factors of two to three overall, up to a factor of 10 in heating requirements) can be achieved in retrofitting existing buildings compared to their pre-existing energy use, but it is generally not possible to achieve as low an absolute energy intensity as can be achieved in new buildings, and such reductions as can be achieved entail greater cost than if buildings are designed from the beginning to require minimal use of energy. Hence, by delaying programmes to dramatically reduce the energy intensity of new buildings, or the energy intensity of old buildings when they require major renovations, significant windows of opportunity will be lost (irreversibly in the case of new buildings).

Some of the key actions required with respect to new buildings are thus:

- upgrading the teaching of building sciences at universities (in architecture and engineering departments), community colleges and vocational schools with, in particular, the creation of comprehensive, integrated programmes that combine all of the elements needed to create truly sustainable buildings;
- developing university-based outreach programmes to improve the design process among practising design firms (architectural and engineering);

- undertaking 'market transformation' programmes so that high-performance buildings, designed using the integrated design process, are increasingly what the market expects. This could entail financial support for high-profile projects that demonstrate large savings at little to no incremental cost (many examples of which already exist and have been documented in this book), incentives to support the additional cost of design using the integrated design process, and training in the integrated design process;
- rapid upgrading of building codes to eventually require a factor of two to three reduction in energy use compared to current practice for new buildings (with incentives to do even better where possible), providing training in meeting upgraded building codes, and providing enhanced inspection ability to increase the degree of compliance with the upgraded building codes;
- providing financial support for continued improvement and reduction in the cost of a wide array of promising advanced technologies that further increase the potential for reducing the energy intensity of buildings, particularly of the large stock of existing buildings.

Policies to support comprehensive retrofits of existing buildings include:

- provision of low- or zero-interest loans to be used for renovations that achieve a given minimum energy performance, or partial rebates based on estimated energy use before and after renovations;
- legislation to permit the involvement of energy service companies (ESCOs) in public sector buildings, including legislation to permit long-term (up to 25-year) contracts and to permit procurement based on lowest lifecycle cost rather than based on lowest investment cost;
- legislation to require upgrading buildings to attain a minimum energy performance at the time of sale.

Barriers to the involvement of ESCOs, ways of overcoming these barriers and various financing mechanisms are discussed in Goldman et al (2005).

For both new and existing buildings, possible policies include:

- partial rebates to reduce the cost of more efficient equipment (such as boilers, cooling systems, motors);
- mandatory rating of buildings in terms of energy use and mandatory supply of this information to prospective buyers of new or existing buildings;
- continuous strengthening of energy efficiency standards pertaining to heating, cooling and ventilation equipment, appliances, consumer electronic goods (such as computers and entertainment systems), office equipment and lighting.

Lebot et al (2004) note that advertising promoting consumption or purchase of larger equipment can (and is) undermining the benefit of energy efficiency programmes. Most efficiency standards are based on different size categories, so that a large piece of equipment with a favourable energy efficiency rating frequently uses more energy than a smaller piece of equipment with a lower rating. They propose that advertisers be required to give the energy consumption of their products in all advertising, and that energy efficiency standards be based on absolute energy use. Energy requirements for housing (in terms of maximum allowed energy use per unit of floor area) also need to be designed so at to be more stringent the larger the house. However, as discussed by Harris et al (2008), the current Home Energy Rating System (HERS) in the US in effect requires smaller houses to have a more efficient furnace than larger houses in order to attain the same score.

Power utilities can be required to provide demand-side management (DSM) programmes, and rate structures (which are subject to government regulatory approval in the case of private utilities) should be designed to reward utilities that achieve deep energy savings for their customers at the lowest possible cost.

At the community scale, government support for district energy systems is required even in circumstances where they make economic and environmental sense.[5] This can entail direct financial involvement, enabling legislation in cases where there are legal barriers and expeditious review and permitting of proposals.

## 11.4.2 Transportation

The objectives of reducing energy use and GHG emissions from passenger road transportation are likely to be only two of many objectives related to passenger transportation. There are many approaches that can be taken to achieving energy-related and non-energy-related objectives with regard to passenger transportation. The approaches can be grouped into a small number of broad strategies. Box 11.1 outlines 15 possible transportation-related objectives, 4 strategies and 24 specific policy actions. Some strategies may, if carried out in isolation, achieve one objective while hindering other objectives. For example, an increase in fuel economy alone may lead to an increase in driving and an increase in congestion and traffic deaths by making the cost of driving a given distance less expensive. Imposition of higher fuel economy standards will probably increase the cost of a given vehicle, leading to a delay in the replacement of old (and inefficient) vehicles with newer vehicles. Thus, with regard to the fuel efficiency of the automobile fleet, dramatically higher (factor of two) fuel economy standards should be accompanied by steadily increasing fuel taxes (but perhaps adjustable so as to smooth out the effect of large fluctuations in the price of oil) and possibly some system of rebates on vehicles that are more efficient than the average and surcharges on vehicles that are less efficient. Anecdotal evidence indicates that the sharp spike in the price of oil in 2008 (reaching \$150/barrel), which is probably a forewarning of long-term prices, began to affect

### Box 11.1 Possible policy objectives and approaches related to passenger transportation energy use in urban areas

#### Transportation policy objectives

1. Reduce air pollution
2. Reduce GHG emissions
3. Reduce traffic congestion
4. Reduce amount of land taken up with parking lots
5. Reduce traffic accidents and deaths
6. Reduce consumer monetary costs for travel (especially as oil prices rise)
7. Reduce commuter stress and commuting time
8. Reduce facility costs (especially for provision of parking)
9. Reduce upstream environmental impacts (oil spills, tar sands in Canada)
10. Reduce potential for war over dwindling oil supplies (more relevant to the US)
11. Conserve non-renewable resources[a]
12. Promote physical fitness and health
13. Improve community liveability
14. Improve the aesthetic appeal of cities
15. Promote local economic development (through more local spending of local income)

#### Overall strategies related to the objectives outlined above

1. Implement more stringent pollution emission standards
2. Implement more stringent fuel efficiency standards
3. Implement measures to reduce the total number of trips and distance travelled
4. Implement measures to change the modal split (in favour of non-automobile options)

**Specific policy options**

## Related to average fuel economy of the automobile fleet

1 Mandated improvement in average new car fleet fuel economy (CAFE standards)
2 Gas-guzzler purchase tax (to increase market demand for fuel-efficient vehicles)
3 Increase in gasoline tax (to increase market demand for fuel-efficient vehicles and to prevent the effective price of gasoline from falling due to more efficient use)
4 Enforcement of speed limits (improves actual on-road fuel economy)
5 Public education (benefits of engine maintenance, proper tyre pressure, less aggressive driving, no idling)

## Related to air pollution emissions

6 Strengthen pollutant emission standards
7 Strengthen fuel quality standards (especially sulphur, cetane and aromatics content)
8 Improve enforcement of emission standards
9 Public education/exhortations

## Related to total amount of travel, timing and modal split

10 Urban intensification (smart growth, infill)
11 Major public transportation infrastructure improvements
12 Incremental improvements to public transportation
13 Road pricing
14 Parking management (supply, cost, shared use, unbundling)
15 Pay-as-you-drive insurance
16 Promote car sharing
17 Promote car pooling
18 Promote telecommuting
19 Promote off-peak travel (via variable road pricing, for example)
20 Promote HOV (high-occupancy-vehicle) lanes
21 Improve walking/bicycling environment
22 Promote shift of freight to rail
23 Promote walking school buses
24 Provide student discounts for public transportation

*Note:* [a] This includes not only oil, but also – in the case of petroleum products made from the Canadian tar sands – the substantial amounts of natural gas that are used in upgrading the tar.

consumer personal vehicle choice, driving, air travel and freight transport. For a further discussion of policy packages that simultaneously achieve multiple objectives, see Litman (2007).

With regard to freight transportation, a combination of mandated fuel efficiency improvements for trucks combined with government support for research and development of new technologies and a steadily increasing carbon tax could achieve significant reductions in energy use per tonne-km of transport. Transport by rail can be encouraged through a steadily increasing carbon tax. At present, aviation fuel is not subject to any tax (and is not subject to any restrictions under the Kyoto Protocol).

Subsidies for the production of ethanol from corn or other starchy crops should cease immediately, as the energy and GHG benefits are small at best, there are other more effective ways to reduce transportation fossil fuel energy use (as outlined in Box 11.1) and the use of biomass for biofuels is the least effective in reducing $CO_2$ emissions of the various ways in which biomass can be used (see Volume 2, Table 4.56). Biodiesel is potentially attractive but caution is required in stimulating its use due to the potential of negative social and environmental impacts if development is rapid, uncontrolled and not matched to the availability of surplus agricultural land.

A critical factor in reducing long-term emissions from the transportation sector is appropriate urban form (densities and mixes of land use) coupled with the provision of high-quality rapid-transit infrastructure and support for bicycling and walking as alternatives to private motorized transport. For existing urbanized areas, this will require urban intensification, which is subject to a number of non-technical obstacles but is certainly aided by the decreasing economic viability of low-density suburbs in the face of rising transportation fuel costs.

### 11.4.3 Industry

In the industrial sector, the most effective policies to reduce energy use per unit of output are likely to be negotiated voluntary agreements, government support for long-term research and development, and tax incentives to invest in newer and more efficient equipment. Mandatory standards are likely to be unworkable because of the complexity of industrial energy use and its dependence on highly site-specific conditions (such as the particular mix of products produced at a given facility). Rietbergen et al (2002) deduced that one quarter to one half of the energy savings in Dutch industry since 1992 can be attributed to the long-term agreements that have been the main policy instrument for industrial energy efficiency in Holland since 1992. Social mechanisms, such as the establishment of local social networks with group targets, can be used to motivate management to pay more attention to energy efficiency (Jochem and Gruber, 2007). Information programmes and free energy audits seem to be preferable to long-term agreements for small- and medium-sized industrial firms, as small firms usually do not have the staff or knowledge to design and implement energy efficiency measures (Thollander et al, 2007). Broad support for high rates of recycling throughout society will also contribute to reduced energy use per unit of output, as the energy required to produce metals, plastics and paper from recycled materials is generally much less than making these products from raw materials (see Table 6.4).

### 11.4.4 Power utilities and cogeneration

In most parts of the world, cogeneration by independent power producers is blocked by electric utilities, or by government regulations (such as the prohibition, in the US, of running private electrical wires across public streets, thereby preventing potential cogenerators of electricity from selling it to potential adjacent customers or even to their own adjacent operations). Opportunities to generate electricity from hot exhaust flows to produce electricity (discussed in Chapter 6, subsection 6.14.1) are also blocked in the same way, and do not qualify in meeting Renewable Portfolio Standards in most US states, even though no incremental fossil fuel energy is required (Casten and Ayres, 2007). In other instances, power utilities can effectively block cogeneration by accepting only highly unfavourable rates for the purchase of cogenerated electricity. Dismantling existing regulatory barriers and the monopoly powers of electric utilities could therefore facilitate the rapid deployment of large amounts of efficient cogeneration capacity.

## 11.5 Promoting diets low in meat and with less embodied energy

As noted in Chapter 7 (subsection 7.9.3), there is (in the case of Sweden) a factor of four difference in the fossil fuel energy embodied in low-energy and high-energy meals with comparable nutritional value and meat content. Meat itself requires many times more original phytomass than direct consumption of plants for food. The ratio of phytomass energy input to the agricultural system to food energy output is about 1:1 for fresh fruits and vegetables and 1.5:1 for processed foods, but ranges from as little as 6:1 for fatty poultry to over 200:1 for beef (see Table 7.15). Meat-based diets thus require vastly greater amounts of land than a vegetarian diet. In the great majority of cases, this land could instead be used to produce bioenergy crops that could displace fossil fuels. If adjustments are made to account for possible differences in the yield of crops for animal feed versus bioenergy crops, and for differences in the efficiencies with which bioenergy crops and fossil fuels can be used, the phytomass energy input can rightly be added to the direct fossil fuel energy inputs to give the overall potential impact of the consumption of food products on the demand for fossil fuels. When this is done, diet emerges as the single most important factor in determining energy use and GHG emissions that is subject to direct control by consumers.

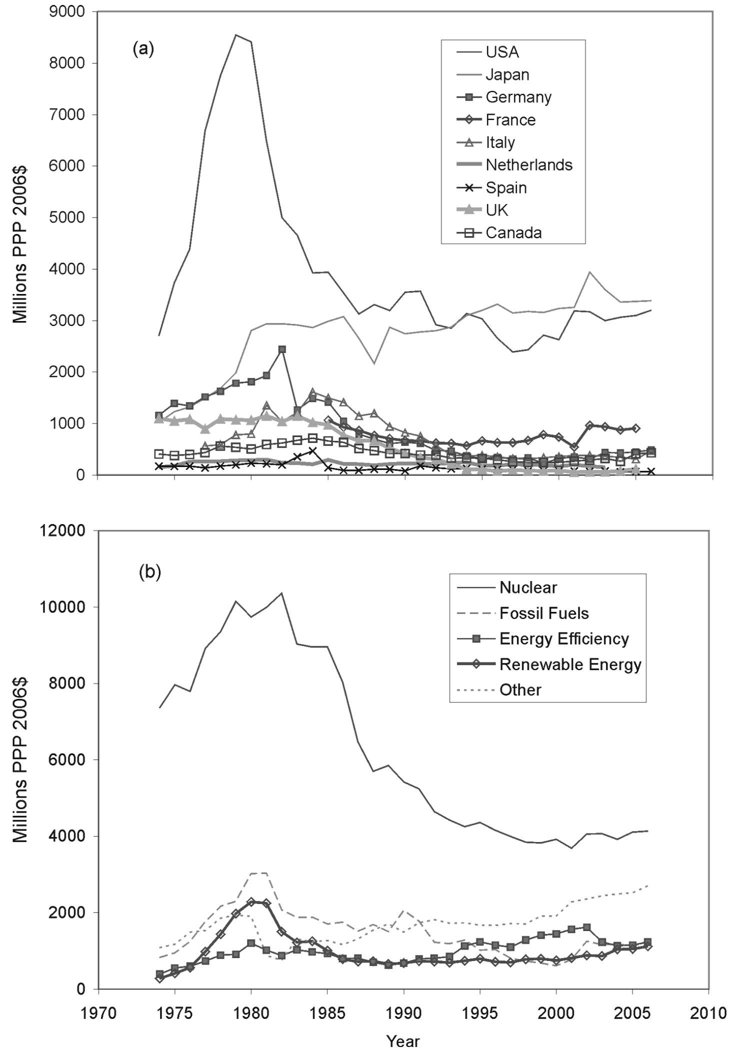
As discussed in Volume 2 (Chapter 4, subsection 4.9.2), for scenarios with relatively low meat consumption, a significant fraction of future energy needs could be met with bioenergy crops grown on surplus agricultural land. Significant methane and nitrous oxide emissions are associated with livestock (although these can be reduced to some extent through improved feed and better handling of wastes). Promotion of diets with low meat and low embodied energy is thus an important strategy in reducing future GHG emissions. This can be done by:

- eliminating all subsidies for feed grain and livestock producers (equivalent to $2.9 billion/year in the US alone);
- imposing strict environmental and labour standards on livestock operations (thereby increasing market costs while non-market costs decrease);
- perhaps providing financial support for vegetable and fruit production;
- imposing a heavy tax on sugar;
- eliminating all subsidies for fisheries (these currently amount to about $30–40 billion/year worldwide according to Halweil and Nierenberg (2008));
- creating greater public awareness of the health risks of high-meat diets, which have been linked to coronary heart disease, type II diabetes, many forms of cancer and the increase in obesity in the US (Mann, 2002; Key et al, 2004; Chao et al, 2005).

Consumption of food is a social and cultural expression of individuals, but the development of the corporate food economy has increased the separation of people from their sources of food (Levkoe, 2006). In many cities, grassroots organizations have arisen to counter this tendency through the promotion of urban agriculture, markets for local producers and awareness of the environmental and social-justice implications of alternative food choices. The development of youth community gardens has been shown to positively influence dietary behaviour and to enhance environmental awareness and appreciation (Lautenschlager and Smith, 2007). Government support for such grassroots movements could therefore contribute to a long-term social transition to greater awareness of the environmental (and social) implications of alternative dietary choices, and could contribute to a decline in per capita meat consumption. Such support would parallel the support for Simplicity Circles and similar groups advocated above.

## 11.6 Research and development in energy efficiency and renewable energy

Most of the technologies needed to achieve dramatic reductions in energy use and a significantly increased use of renewable energy already exist and have been used successfully in at least some jurisdictions. There is, nevertheless, a role for continued technological development in reducing the cost and increasing the market penetration and technical performance of many technologies. However, government support for research and development in the areas of energy efficiency and renewable energy has been stagnant for the past decade, in spite of increasing awareness of the urgency of dealing with the global warming problem. Figure 11.6a shows the variation in total energy research and development spending by selected governments between 1974 and 2006.[6] There was a major spike in research and development during the time of high oil prices in the late 1970s and early 1980s, but (with the exception of Japan) this support fell when the price of oil fell. Total research and development spending (in 2005$) among 26 out of 30 IEA countries[7] peaked at $18.2 billion in 1980, fell to a minimum of $8.3 billion in 1997, then rose modestly to $10.2 billion in 2006. However, during this time period, energy research and development has been overwhelmingly directed toward nuclear energy, as shown in Figure 11.6b. Figure 11.7 shows the relative shares of energy research and development support in 2006 given to nuclear energy, fossil fuels, renewable energy, energy efficiency, hydrogen and fuel cells, electricity (including transmission) and energy storage, and other (which includes energy systems analysis). Nuclear energy (which cannot make a significant contribution to reducing GHG emissions at a global scale according to the analysis presented in Volume 2, Chapter 8, section 8.11) took 39 per cent of total

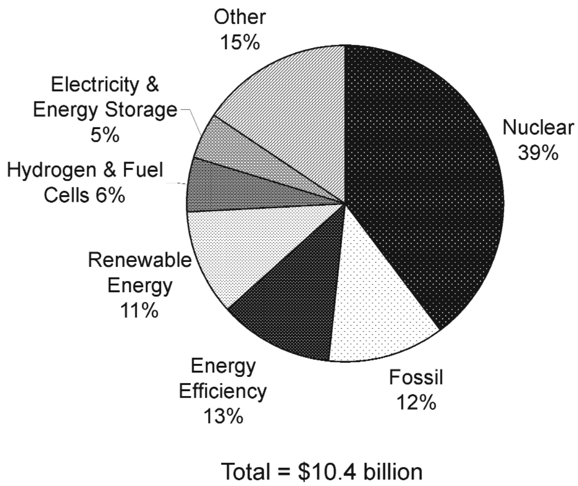



*Source:* Data from IEA Energy Technology R&D online database at www.iea.org/Textbase/stats/rd.asp

**Figure 11.6** *Government support for energy research and development from 1974 to 2006: (a) for selected countries belonging to the IEA, and (b) by energy sector*

energy research and development funding by IEA governments, while energy efficiency and renewable energy (the focus of this book and of Volume 2 because of their overwhelming importance) together took only 24 per cent of total funding.[8]

Given the urgency of the global warming problem and the lack of significant increases in government funding of energy research and development during the past decade (particularly in comparison to the response to the 1970s' oil price shock), there is a clear need to dramatically increase funding levels, *particularly in the areas of energy efficiency and renewable energy*. Indeed, substantial increases in the funding of these critical areas could be accomplished by simply redirecting a significant fraction of the disproportionately large nuclear support into these areas. Funding increases should be accompanied by measures to increase the rate of uptake and diffusion of innovations in the energy




*Source:* Data from IEA Energy Technology R&D online database at www.iea.org/Textbase/stats/rd.asp

**Figure 11.7** *Allocation of energy research and development funding by IEA member governments in 2006*

sector, as discussed by Gallagher et al (2006). Kammen and Nemet (2007) argue that increased government research and development support in the energy sector would leverage additional research and development from the energy industry (whose funding has also been falling recently, at least in the US).

For the sake of completeness, an overall discussion of where research priorities should lie both with regard to energy efficiency (the subject of this book) and with regard to renewable energy (the subject of Volume 2) is presented next. The priorities listed below are based on my expectations of where important reductions in the cost and improvements in the technical performance of technologies already under development could occur.

In the buildings sector, priorities are:

- LED lighting;
- vacuum insulation (especially useful in retrofit applications);
- phase-change materials in insulation;
- smart (electrochromatic) windows;
- heat pumps using non-halocarbon working fluids for integrated space and water heating and air conditioning;
- solar air conditioning and combined solar space and hot-water heating;[9]
- solar retrofits of existing buildings.

In the transportation sector, priorities are:

- batteries and supercapacitors for use in plug-in hybrid vehicles and as part of a V2G system to provide storage for renewably generated electricity;
- improved performance and emissions of light- and heavy-duty diesel vehicles;
- lightweight and strong materials for road and air transportation;
- fuel cells for various transportation applications;
- development of biofuels from lignocellulosic feedstocks.[10]

In the industrial sector, the priority is fundamental research pertaining to chemical processes and nanotechnology, although there are promising possibilities for further improvement in energy efficiency throughout the industrial sector (such as outlined in Chapter 6, subsections 6.7.7 and 6.9.3).

In the agricultural sector, the priority is research on how to maintain current yields (or close to current yields) in low-energy (such as organic) agricultural systems in all regions of the world.

In the electricity supply sector, priorities are:

- crystalline and thin-film silicon modules;
- concentrating solar thermal electricity production;
- compressed air underground storage for use with wind;
- advanced gasification and cogeneration using biomass fuels;
- enhanced geothermal systems;
- ocean wave, tidal, current and thermal energy systems;
- carbon capture and storage (to accelerate the reduction in $CO_2$ emissions while fossil fuels are being phased out, and for later application to biomass carbon so as to create negative emissions).

The technology dynamics literature identifies the possibility of two different future technology paths: the first, a carbon-intensive path, in which gaseous and liquid fuels are made from coal and replace conventional gaseous and liquid fuels as they are depleted (this assumes that the available coal resource is large, an assumption that is questioned in Chapter 2, subsection 2.5.3); and the second, a low-carbon path, in which biomass, solar, wind and other renewable energy sources gradually replace fossil fuels as conventional fuels are depleted. Because initial developments along either path will lead to cost reductions through learning-by-doing, it will be very difficult to switch from one path to another once we have started down one path. This phenomenon is referred to as 'carbon lock-in' and already characterizes the present energy system (Unruh, 2000, 2002). Thus, if we do not want a carbon-intensive future, or if we do not want to begin travelling a path that will have to be aborted at great cost, then governments should *not* support research and development of various processes for making gaseous and liquid fuels from coal. If the mineable coal resource is as small as suggested in Chapter 2, this path will have to be aborted in any case, so the investment will largely be wasted, additional $CO_2$ will have been emitted (even if carbon capture and storage of large point sources can be widely deployed) and the development of a sustainable energy system unnecessarily delayed.

## 11.7 Rebound effects

It is widely recognized that improvements in energy efficiency, while directly reducing energy use, indirectly lead to an increase in the demand for energy that partly undoes some of the direct energy savings. This indirect increase in energy use is referred to as the *rebound effect*. As discussed by Greening et al (2000), four different rebound effects are recognized:

- a *direct rebound effect*, through the decrease in the cost of energy services due to the need for less energy, leading (usually) to a greater demand for that service;
- an *indirect rebound effect*, whereby the money saved due to less expenditures on energy is spent on other goods and services that in turn require energy;
- a reduction in the *real* price of energy due to less total demand for energy (this is referred to by economists as a *general equilibrium effect*, or economy-wide effect due to changes in the prices and consumption of goods and services throughout the economy);
- *transformational effects*, which are changes in consumer preferences, alterations of social institutions and changes in the organization of production.

Various studies indicate that, in aggregate, these rebound effects are small – reducing the energy savings by at most a few per cent (Laitner, 2000), in the order of 5–15 per cent (Schipper and Grubb, 2000), no more than 25 per cent (Binswanger, 2001), or around 26 per cent (Barker et al, 2007). This is because, for most activities, energy costs represent only a few per cent of the total costs. However, where energy use is strongly constrained by price (such as heating of poorly insulated houses of poor people), an increase in energy efficiency (such as more insulation and better windows) will be offset to a much greater extent by increased provision of energy services (warmer indoor temperatures in the case of poorly insulated houses).

### 11.7.1 Reducing or reversing the rebound effect

The analyses of the rebound effect, cited above, assume that the energy savings lead to net cost savings. In reality, equipment or actions to reduce long-term energy use often require a greater upfront investment than less efficient equipment, and payments on this extra investment will offset some or all of the energy cost savings. For example, higher levels of insulation and high-performance windows in residential buildings generally entail greater overall building costs, which can be financed through an increase in the monthly mortgage payments. Similarly, more fuel-efficient automobiles would cost more for the same performance (such as acceleration) and amenity value (such as size) as less fuel-efficient vehicles. If energy-saving measures are pushed to the point where they are just cost effective over the lifetime of the measure (that is, such that annual energy cost savings equal annual financing costs including interest), then the sum of the first two rebound effects will be zero or close to zero. If energy-saving measures are implemented that exceed that which is cost effective in purely monetary terms, then there would be a *negative* net rebound – energy will be saved due to the net reduction in yearly funds available to be spent on other things, in addition to the savings arising from more efficient equipment.

This would occur in the case of high-performance windows, for example, that replace low-performance windows in part for aesthetic reasons. If a consumer replaces windows with high heat loss with high-performance windows because they look better, and spends more than can be economically justified based on energy cost savings, the consumer is spending money to buy an intangible service (better-looking windows). The energy cost of this service is the extra embodied energy beyond that of a window that would just be cost effective. If the ratio of the extra embodied energy to the extra cost (MJ/$) is less than that of the goods and services that the extra money would otherwise be spent on, then there will be a negative rebound effect.

The relationships between energy and financial costs and savings, and the rebound effect, are illustrated in Table 11.1 for the case of the replacement of low-performance windows with high-performance windows. Window costs, embodied energy and annual energy savings roughly correspond to a retrofit recently performed on the author's house. This retrofit was not cost effective from a purely economic point of view at the retail cost of heating energy (natural gas) at the time of the retrofit ($11/GJ), but lead to a marked improvement in the appearance of the house and in convenience (the replacement windows on the second and third floors can be easily cleaned on the outside). A cost recovery factor (see Appendix D) can be computed based on the interest rate and assumed time period over which the purchase of the window is financed; this times the purchase cost of the window gives the annual cost of the window including interest (the interest rate corresponds either to the interest rate on the home mortgage, or the foregone interest on an alternative risk-free investment). The direct energy savings due to the window is the reduction in heating energy use. The indirect effect of the window on energy use consists of that due to the reduction in annual energy costs (the first rebound effect, which is an increase in energy use because the savings in annual heating costs can be spent in other ways) and that due to the initial purchase cost of the window and the cumulative interest paid until the principle is paid back (money used to pay for the window plus interest cannot be used on plane trips, for example). The reduction in energy use due to the purchase cost plus interest is equal to the annual financing cost of the window times the number of years over which the window is financed (this gives the cumulative cost of the window, including interest) times the energy intensity (MJ/$) of alternative expenditures.[11] For the assumptions given in Box 10.1, and assuming that the money spent on the window would have been spent on other products with the *average* Canadian energy intensity (10MJ/$), the first and second rebound effects together form a negative rebound of about 40 per cent if the window is financed over a 20-year time

**Table 11.1** *Analysis of the rebound effect associated with the purchase of energy-efficient windows*

| | | |
|---|---|---|
| *General inputs* | | |
| Window cost ($/m²) | 450 | |
| Window embodied energy (GJ/m²) | 2.0 | |
| Reduction in annual heat loss (GJ/m²/yr) | 0.59 | |
| Efficiency of heating system | 0.90 | |
| Annual heating energy savings (GJ/m²/yr) | 0.65 | |
| Cost of heating energy ($/GJ) | 11 | |
| Annual energy cost savings ($/m²/yr) | 7.18 | |
| **Energy intensity of window (MJ/$)** | **4.44** | |
| Canadian GNP in 2005 (trillion $) | 1.079 | |
| Canadian primary energy consumption in 2005 (EJ) | 10.85 | |
| **Average energy intensity of Canadian expenditures (MJ/$)** | **10.06** | |
| *Specific inputs and results* | | |
| Interest rate | 0.04 | 0.04 |
| Financing period (yr) | 20 | 50 |
| CRF (cost recovery factor) | 0.074 | 0.047 |
| Annual cost of window ($/m²) | 33.11 | 20.95 |
| Annual energy cost savings ($/m²) | 7.21 | 7.21 |
| Net annual cash flow ($/m²) | –25.90 | –13.74 |
| Direct energy savings during financing period (GJ/m²) | 13.11 | 32.78 |
| Indirect energy savings due to purchase of window (GJ/m²) | 6.66 | 10.53 |
| Indirect energy savings due to reduced annual energy cost (GJ/m²) | –1.45 | –3.63 |
| Indirect energy savings (GJ/m²): | 5.21 | 6.91 |
| Overall energy savings (GJ/m²)[a]: | 16.32 | 37.68 |
| Rebound effect (%) | –39.73 | –21.07 |

*Note:* The analysis presented here is based on the total window cost and embodied energy, which is appropriate when it is not strictly necessary to replace the window. Otherwise, the incremental cost and embodied energy when a high-performance window is chosen should be used.

period, and 20 per cent if financed over a 50-year period.[12] That is, the reduction in energy use due to the author having less money available to spend on other things adds 20–40 per cent to the energy savings arising directly from the better windows.

The policy implications of the above examples are that:

- governments should push energy efficiency measures to the point of cost effectiveness (so that there is no net annual cash flow savings and hence no rebound effect);
- governments should promote energy efficiency measures on the basis of their non-economic co-benefits (so that they are done even when there is a net monetary cost, thereby creating a negative rebound), as well as on the basis of their economic benefits; and
- incentives for energy-efficient consumption need to be coupled with incentives to work less (as discussed in subsection 11.2.2) or increases in the cost of energy (through a carbon tax, for example), so that there is a decrease in overall consumption.

Note that if energy efficiency is motivated by an increase in the cost of energy, then energy efficiency measures serve to reduce the impact of this cost increase. If the cost increase is so large that large parts of the population would be forced to do without some energy services, or to cut back in essential consumption (such as food purchases), then the effect of efficiency improvements is to permit maintenance of close to the previous energy service levels while reducing energy use relative to the previous rate of energy use. In this case there would be no rebound relative to previous rates of energy use.

Alfredsson (2004) discusses the rebound on $CO_2$ emissions associated with a shift to a 'green' diet (i.e. one with less meat and processed foods), which can cost less as well as reduce the energy required to supply and cook the food. He finds, using Swedish data on the marginal propensity to spend (that is, how additional income tends to be spent), that the $CO_2$ emissions associated with the reallocation of the saved money exceeds the direct reduction in emissions associated with the shift to a green diet. That is, the rebound effect is greater than 100 per cent. This is because the difference in kgC/$ between green and non-green diets is less than the average kgC/$ of the saved money that is spent in other ways. However, this analysis does not take into account the additional biomass energy that could, in principle, be produced on the surplus land that becomes available with a shift from a high-meat to a low-meat or vegetarian diet (see Volume 2, Chapter 4, subsection 4.9.2).

Furthermore, 'green' diets may cost more (particularly diets consisting of organically certified food) but are also healthier. Thus, promotion of green but more expensive and less energy-intensive diets on the basis of health will provide additional environmental benefits through the reduction in money available to be spent by consumers on other products or services (which unavoidably entail the use of energy, whether direct or indirect).

## 11.7.2 Non-economic constraints on the use of energy

Hofstetter et al (2006) have pointed out that cost is only one of several factors that constrain energy-using activities. They list five limiting factors that can cause positive or negative rebound effects: cost, time, space or volume, skills and information.

If a low-energy activity requires more time, then the time available for more energy-intensive activities will decrease, leading to a further reduction in energy use. This is a negative rebound effect – subtracting further from energy use (adding to the initial energy savings), rather than adding energy use. Examples include bicycling instead of driving (although sometimes bicycling is faster!) or promotion of leisure activities such as gardening through the provision of rooftop gardens. Rooftop gardens have very little direct impact on the heating and cooling loads of buildings and only a modest impact on transportation energy use if food is grown in place of food imported from elsewhere, but they could induce large indirect impacts if, for example, the owners of the garden tend them on weekends instead of driving to the countryside. Similarly, if parking lots are converted to gardens in order to discourage car use, there could be a sizeable negative rebound. To the extent that greater insulation levels in the walls of houses reduce the available interior space, residents will tend to buy less material goods – or perhaps smaller goods – as there will be less space to store them. Acquisition of a pet such as a dog increases energy use (through the provision of dog food), but this could probably be overwhelmed by the loss of time for energy-intensive activities due to the time required to walk the dog one or two times per day.

### 11.7.3 Sufficiency as a complement to efficiency

The fundamental problem with a focus solely on efficiency is that, in the face of unlimited human demands, greater efficiency makes it possible to produce or obtain more, rather than reducing environmental impacts and the rate of resource depletion at the pre-existing level of consumption. For this reason, the widespread recognition of the need for *efficiency* needs to be complemented by widespread acceptance of the idea of *sufficiency* – that at some point, we must learn to be satisfied with what we have, an idea that is elaborately developed in Thomas Princen's book *The Logic of Sufficiency* (Princen, 2005). We must learn to strive for what is sufficient rather than the maximum possible that we can, or think we can, attain. Acceptance of sufficiency implies conservation – voluntary consumption of less (in the near term) than one could consume. This in turn implies discipline, an orientation away from material values, and caring for common interests.

For some people, the restrictions on energy use needed to avert future ecological catastrophe might be regarded as a sacrifice. Any required 'sacrifices' will, however, be small and will be compensated by multiple benefits in the present. And certainly, we should not complain about making small 'sacrifices' for the well-being of future generations or for the well-being of the many other species with which we share this planet. In the words of Gandhi in 1925:

> No sacrifice is worth the name unless it is a joy.
> Sacrifice and a long face go ill together.
> He must be a poor specimen of humanity
> who is in need of sympathy for his sacrifice. ('Quotes of Gandhi', compiled by Shalu Bhalla, UBS Publishers' Distributors, New Delhi, 2005)

## 11.8 Reflections on the primal role of economic growth today

The analysis presented in Chapter 10 has underlined the importance of reducing the rate of economic growth in achieving deep reductions in absolute energy use.[13] The need to limit economic growth will be confirmed in Volume 2, in which attempts are made to construct scenarios that meet the global demand for energy and fuels projected under the low and high GDP and the green scenarios of Chapter 10 while reducing $CO_2$ emissions sufficiently rapidly to limit the peak atmospheric $CO_2$ concentration to no more than 450ppmv. In order to provide an opportunity for developing countries to improve the material standard of living of their people (which is desperately needed in many parts of the world), economic growth must at least temporarily pause in the already-rich countries. Indeed, a modest downsizing of the economies of the rich countries would be highly beneficial. Earlier in this chapter, a variety of strategies for reducing consumer spending – which is the ultimate driver of economic growth – were outlined. However, the response of the political leaders of the rich countries to the economic crisis that began in late 2008 has been to dramatically and, in some cases, dangerously increase government deficits in an effort to quick-start their economies, hoping to get them back onto a growth trajectory driven by ever more consumer spending.[14] And perhaps without exception, the present world leadership is determined that measures to reduce GHG emissions should not in any way slow down economic growth. Thus, economic growth is primary, climate stabilization – even avoiding future ecological and humanitarian disaster – is secondary.

Why the current fixation on economic growth above all else? Early economists such as John Stuart Mill, and more recently even John Maynard Keynes himself (whose writings are now being invoked to justify massive government stimulus spending) envisaged a time when economic growth would have to stop. Keynes foresaw a time when the 'economic problem' would be solved and 'we prefer to devote our energies to non-economic purposes' (Keynes, 1930).

The reasons for the current universal fixation on economic growth are nicely elucidated in two recent books, *Managing Without Growth: Slower by Design, Not Disaster*, by Peter Victor (2008), and *Prosperity Without Growth: Economics for a Finite Planet*, by Tim Jackson (2009). The fundamental problem is that the current world economy is structurally dependent on growth for stability. If it is not growing, it tends to spiral into depression. Economic growth has been the default mechanism for preventing collapse, and those who question growth have, in the words of Jackson, been regarded as lunatics, idealists or revolutionaries. Because the idea of limits to growth is so foreign to most people, Peter Victor goes to great length – taking up almost half of his book – carefully making the case that the rich countries have little choice but to learn how to manage without growth. His argument is not that we should adopt zero growth as an overarching policy objective, but rather, that we should not bother with growth as a policy objective at all, or at least only as secondary to more specific objectives that have a clearer connection to human well-being. Avoiding catastrophic climatic change should certainly be one of those objectives.

However, for the past few decades, government policies of all sorts have been evaluated in part (some would say largely or entirely) through how they contribute to economic growth. In the words of Tim Jackson (2009, p6):

> the growth imperative has shaped the architecture of the modern economy. It motivated the freedoms granted the financial sector. It stood at least partly responsible for the loosening of regulations and the proliferation of unstable financial derivatives. Continued expansion of credit was deliberately courted as an essential mechanism to stimulate consumption growth.

In words of Peter Victor (2008, pp1–2):

> economic growth is the policy objective against which all other proposals must be judged. Environmental policy must not be allowed to impede growth, and where possible should be advocated because it will boost growth… Education policy must see that students are trained for work in the 'new economy'. Transportation policy should result in a more rapid movement of goods. Immigration policy should attract the most highly educated and the wealthiest to meet the needs of a growing economy. Support for the arts is based on [their] economic contribution. All are judged against their contribution to growth.

What is needed is to move climatic change and reduction of GHG emissions to the place now held by economic growth. All other policies must now be evaluated, at least in part, in terms of how they contribute to the overarching goal of reducing GHG emissions. A price needs to be set on carbon that is initially high enough, and increases at a sufficiently rapid rate, that climate-related targets – such as limiting atmospheric $CO_2$ concentration to no more than 450ppmv and then drawing down the concentration to 350ppmv or less – are met.[15] How high this price needs to be depends in part on how effective governments are in facilitating the transition to much greater levels of energy efficiency (through the policies outlined in Sections 11.4 and 11.6) and in facilitating the transition to C-free energy sources (discussed in Volume 2). The economy will then adapt, with the economic impact of a high carbon tax (or revenues from auctioning limited emission permits) strongly dependent on how the revenues are recycled. However, some of the massive carbon revenues will surely be needed to pay down some of the massive government debt that continues to build up.

With economic growth no longer emphasized in government policy, and with both consumers and governments living within their financial means (and moving in the direction of living within the planet's ecological and biophysical means), economic growth will slow. The fundamental problem is that there is very little understanding of how to manage an economy that is not growing, or that grows only slowly. In the words of Tim Jackson (2009, p77)

> virtually no attempt has been made to develop an economic model that doesn't rely on long term growth… we have no model for how common macro-economic 'aggregates' (production, consumption, investment, trade, capital stock, public spending, labour, money supply and so on) behave when capital doesn't accumulate… In short, there is no macro-economics of sustainability and there is an urgent need for one.

Initial, tentative steps in this direction have been carried out by Peter Victor (2008) – one of the few economists to begin to study how a non-growing economy would function and maintain stability. Key elements are for increased productivity to flow into decreased working hours (as argued earlier in this chapter), and for a shift from private investment directed toward more consumption, to public investment directed toward social assets. However, the economics profession as a whole urgently needs to address the question of how to maintain stability, solvent government finances and human prosperity in the broadest sense of the word without depending on never-ending economic growth.

This is part of the New Reality posed by the prospect of large, rapid and catastrophic climatic change.

## Notes

1 More precisely, as defined in Wikipedia, the fertility rate is the average number of children that would be born to a woman over her lifetime if (1) she were to experience the exact current age-specific fertility rates through her

lifetime, and (2) she were to survive from birth through to the end of her reproductive life. It is obtained by summing the single-year age-specific rates at a given time.

2 The doubling time in years for any quantity that grows exponentially is equal to roughly 70 divided by the percentage growth rate per year. This can be derived from the expression $P(t)/P(0) = \exp(at) = 2.0$, where $a$ is the fractional growth rate per year ($a = 0.035$ for 3.5 per cent/year growth).

3 Examples include reducing the income gap between rich and poor through a more progressive tax structure, provision of free universal health care where not already available, and greater investment in quality public education (Sanne, 2002). If lower-income people work less because they get to keep more of their income, their total expenditures have not likely decreased (although if the tax reduction for lower-income groups is financed by a tax increase on higher-income groups, they will have less to spend on energy-intensive goods and will have an incentive to work less, so there could be a reduction in overall consumption). Although providing free health care and free quality education are laudable goals (and, indeed, can be regarded as basic human rights), they will not lead to a net reduction in spending on energy-intensive goods unless financed by tax increases (as will usually be required) that are sufficiently large to absorb the private funds formerly spent in these areas.

4 There may, however, be circumstances where narrowly focused and carefully designed short-term subsidies might be justified.

5 District energy systems can be powered by both renewable and conventional energy sources, and so are discussed in Volume 2, Chapter 11, but also affect the demand for energy and so are relevant here.

6 The research and development expenditures shown in Figure 11.6 come from the IEA and have been adjusted by the IEA to be in constant 2005$ and to represent comparable purchasing power in different countries.

7 The IEA countries are also members of the OECD. The countries in the research and development tally are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, The Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the UK and the US. Not included are Iceland, Mexico, Poland and the Slovak Republic.

8 When supporting technologies such as electricity storage, hydrogen and fuel cells are included, the total is still only 35% of total funding.

9 Discussed in Volume 2, Chapter 2.

10 Discussed in Volume 2, Chapter 4.

11 If the average energy intensity of alternative financial expenditures is equal to the energy intensity of the window (MJ/$, given by the embodied energy of the window divided by the cost of the window), then the negative rebound due to the purchase cost of the window will exactly offset the embodied energy of the window. If the annual energy cost saving equals the annual financing cost of the window (meaning that the window just pays for itself over its lifetime), then the two components of the indirect effect sum to zero. If the energy intensity of the alternative expenditure is equal to the energy intensity of the money spent on the window, the indirect effect is still non-zero if there is a net cost of the window over its lifetime.

12 Surprisingly, the energy intensity of dollars spent on long-haul airline flights is comparable to the average of the Canadian economy: a round trip between Toronto and Paris is a distance of 11,500km at an energy intensity of about 0.6MJ/passenger-km (according to Table 5.3) times about 1.7 to account for embodied energy (according to Table 5.4), giving a total of about 1.0MJ/passenger-km. An economy class ticket costs about $1000 (including all taxes and fees). This works out to about 11MJ/$. However, the carbon intensity for air travel would be substantially greater than the economy average.

13 Some would go further and say that economic growth eventually must cease. There is no disagreement that material and energy flows must eventually be stabilized. The question as to whether or not money flows (i.e. GDP) must also be stabilized hinges on the question of whether or not ever more or newer services can be provided that require less and less material and energy throughputs. I suspect not.

14 This is all the more surprising given that part of the consumer spending that drove growth in the rich countries was dependent on growing levels of consumer debt (financed in large part by saving in China) and so was clearly not sustainable.

15 At the 2009 G8 summit, the leaders of the G8 countries accepted a target of limiting climatic change to no more than a 2°C warming above pre-industrial levels. The problem with temperature-based targets such as this is that they do not tell us what the concentration limits for GHGs should be, and thus what we should do (within a range of uncertainty governed by uncertain climate–carbon cycle feedbacks) in terms of emissions. This is because there is a factor of three uncertainty in the climate sensitivity, which relates GHG concentrations to long-term temperature change. Given the likely climate sensitivity of 1.5–4.5°C, there is about a 90 per cent probability that the 2°C target will be exceeded even if we succeed in stabilizing atmospheric $CO_2$ at 450ppmv, and about a 10 per cent probability that we will exceed 4°C. I have previously argued (in Chapter 1, subsection 1.4.1) that a sustained warming of as little as 1°C may be sufficient to provoke an eventual sea level rise of 10–12m.