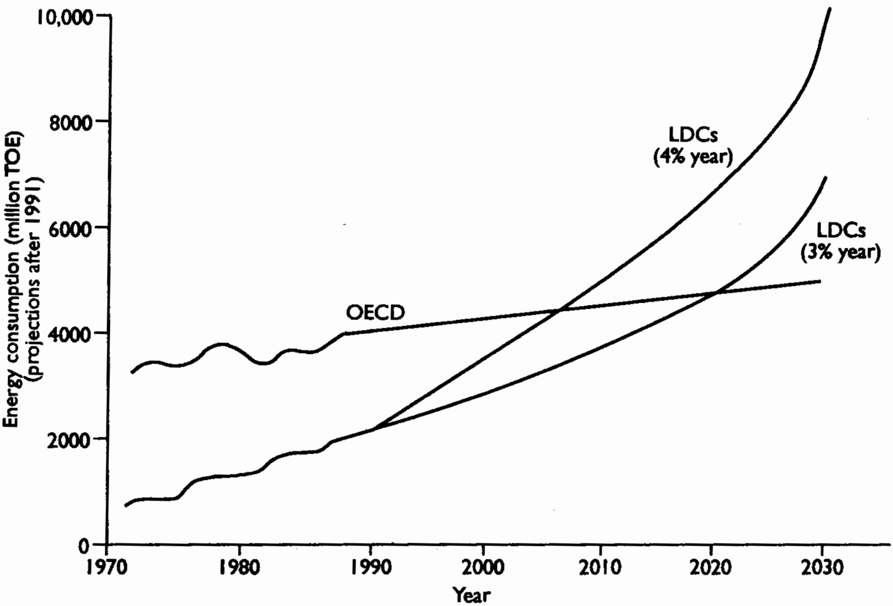
Chapter 6

Global Energy Trends

The world's energy consumption grew by an average of 3.3 per cent per year between 1960–1990 but the growth was very different in developed and developing countries. As shown in Figure 6.1, the energy consumption in the OECD countries has more or less stabilized around 4000 million TOE per year and will probably grow at a rate of not more than 1 per cent per year in the next few decades.



Source: Data from *BP Statistical Review of World Energy* (1990), British Petroleum Company plc, London, UK, up to 1990. From 1991 on, projections.

Figure 6.1 Energy consumption trends in OECD and less-developed countries

On the other hand, consumption has been growing at high rates in dev oping countries and will continue to grow during the next few decades the following reasons:

- Population growth of about 2 per cent per year which, in the aggreg of all developing countries, has been responsible for 50 per cent of annual growth of energy consumption.
- Steady economic growth which, in most parts of the developing wo (with the exception of some African countries), is a result of politi independence, integration into the world economy and access to inf mation via radio and television.

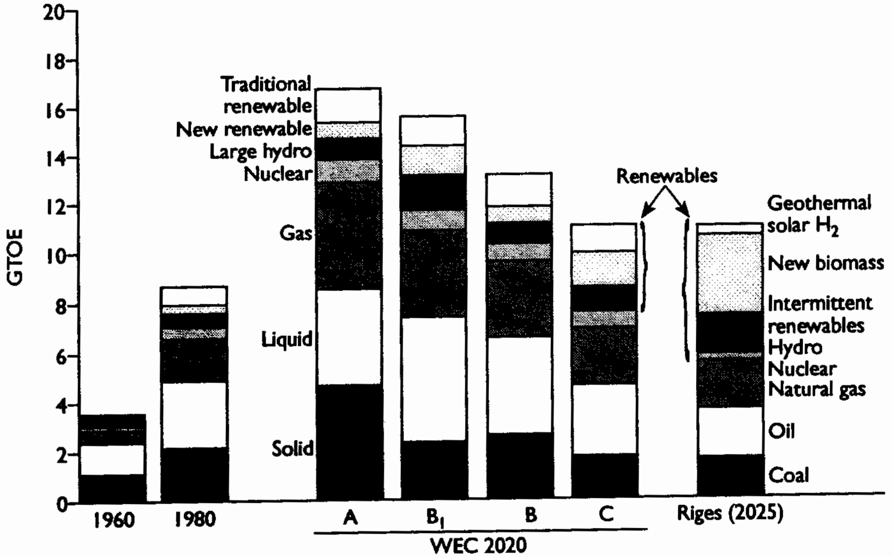
The combination of these two factors has resulted in a growth of commerc energy consumption of about 4 per cent a year in LDCs during the past fe decades, ie a doubling every 17 years.

Between the years 2010 and 2020, energy consumption in the developi countries is predicted to surpass OECD's consumption and, if the prese fuel mix remains unchanged, that will be reflected in the emission of poll tants, particularly CO_2 from fossil fuel burning.

Energy Scenarios

The expected growth in future energy consumption has given rise to severa scenarios constructed to predict the supply-mix in the next century, some o them with an enhanced emphasis on the use of renewables. We shall describ in some detail the recent scenarios of the World Energy Council (WEC) which represent well the spectrum of views presented so far, and are a revision of the earlier WEC projections made in 1983.

The WEC study adopted four possibilities for the future evolution o energy consumption. The projections extend to the year 2020 and their characteristics are given in Table 6.1.



Sources: WEC, *Energy for Tomorrow's World*, World Energy Council, Kogan Page, London (1993) and RIGES, *Renewable Energy – Sources for Fuels and Electricity*, Johansson, T B, Kelly, H, Reddy, A K N and Williams, R H (eds), Island Press, Washington DC, US (1993).

Figure 6.2 WEC and RIGES scenarios

Table 6.1 *Description of the four WEC energy cases 1990–2020*

Case name	*A High growth*	*B1 Modified reference*	*B Reference*	*C Ecologically driven*
Economic growth % pa	High	Moderate	Moderate	Moderate
OECD	2.4	2.4	2.4	2.4
CEEC/CIS*	2.4	2.4	2.4	2.4
LDCs	5.6	4.6	4.6	4.6
World	3.8	3.3	3.3	3.3
Energy intensity reduction per cent pa	High	Moderate	High	Very high
OECD	1.8	1.9	1.9	2.8
CEEC/CIS	1.7	1.2	2.1	2.7
LDCs	1.3	0.8	1.7	2.1
World	1.6	1.3	1.9	2.4
Technology transfer	High	Moderate	High	Very high
Possible total demand (GTOE)	Very high 17.2	High 16.0	Moderate 13.4	Low 11.3

Note: *CIS – Commonwealth of Independent States (former Soviet Union).

Source: World Energy Council, *Energy for Tomorrow's World*, Kogan Page, London, (1993).

The results for the four WEC scenarios are given in Figure 6.2, toget with the results of the RIGES scenario (Renewables Intensive Global Ener Scenarios) prediction for the year 2025. This scenario has adopted the 1 GTOE total primary energy consumption goal of the IPCC, the same level the ecologically-driven scenario C of WEC.

The energy supply assumptions of WEC scenario C and RIGES are giv in Table 6.2.

Table 6.2 *Comparison of scenarios – primary energy consumption in GTOE*

	WEC Scenario C (Year 2020)		*RIGES (Year 2025)*	
Fossil fuels				
Solid		2.1		2.00
Liquid		2.7		1.72
Gas		2.4		2.10
Nuclear		0.7		0.33
Renewables		3.4		5.02
Large hydro	0.9		0.68	
New renewable*	1.4			
Intermittent renewable			0.84	
Traditional renewable	1.1			
New biomass			3.3	
Solar H_2			0.2	
Geothermal				0.04
Total		11.3		11.21

Note: In 'new renewable', 'modern biomass' contributes 0.6 GTOE. This category is considered 'new biomass' in RIGES along with traditional biomass which is all converted into 'new biomass' in the year 2025. The WEC scenario thus gives 1.1 + 0.6 = 1.7 GTOE for 'new biomass' in the year 2020. Subtracting 0.6 GTOE from 'new renewable' in WEC reduces it to 0.8 GTOE for what RIGES considers 'intermittent renewables'. This compares well with 0.84 GTOE in the RIGES scenario.

In WEC's ecologically driven scenario, renewables represent 30 per cent; in RIGES', they represent 45 per cent.

It should be stressed that WEC's ecologically driven scenario, which requires the lowest amount of energy among the four WEC scenarios, incorporates the most testing and far-reaching assumptions for industrialized and developing countries alike, such as:

- A reduction rate in energy intensity far in excess of anything achieved historically, ie a worldwide decrease of 2.4 per cent per year (2.8 per cent per year in industrialized countries). The world's energy intensity is decreasing at 2 per cent per year (2.3 per cent in industrialized countries). In LDCs, the energy intensity would have to decrease by 2.1 per cent per year although it has been growing by 1.2 per cent per year.

- A lower rate of increase in energy demand in the developing countries (less than 3 per cent per year) that would be regarded by many as socially and economically acceptable.
- Very strong policies for promoting energy efficiency and the use of new renewable energy sources.

In the year 2025, carbon emission from RIGES' scenario amounts to 5.5 Gtons, as opposed to 5.8 Gtons for the WEC scenario C and 5.9 Gtons for the actual 1988 global emission. This is much less than the 'business as usual' scenario, such as WEC's A (Table 6.3). This means that, if such scenarios were indeed adopted, they would stabilize the emissions of CO_2 at present levels.

Table 6.3 *Carbon emissions for the WEC and RIGES scenarios*

		Economic growth rate (%)	*Carbon emissions (Gtons of carbon in 2020)**
A (WEC)	High growth	3.8	10.6
BI (WEC)	Modified reference	3.3	9.5
B (WEC)	Reference	3.3	7.8
C (WEC)	Ecologically driven	3.3	5.8
RIGES (2025)			5.5

Note: * Carbon emissions in 1988 were 5.89 Gtons – 'Trends 90, A Compendium of Data on Global Change', Oak Ridge Laboratory, Tennessee, US (1990).

Trends in Energy Intensity

The evolution of the energy intensity ($I=E/\text{GDP}$) over time reflects the combined effects of structural changes in the economy – built into the GDP – and changes in the mix of energy sources and the efficiency of energy use – built into the primary energy consumed E.

Although admittedly a very rough indicator, energy intensity has some attractive features: while E and GDP per capita vary by more than one order of magnitude between developing and developed countries, energy intensity does not change by more than a factor of two. This is due in part to common characteristics of the energy systems of industrialized and developing countries in the 'modern' sector of the economy, and in part to the fact that in industrialized countries energy-intensive activities, such as jet travel, are increasingly offsetting efficiency gains in basic industries.

The factors that determine the evolution of the energy intensity are:

- dematerialization;
- fuel intensity; and
- recycling.

Dematerialization of the economy means using less material for the sa end objective, an example of which is the use of fiberglass to replace copp for telephone transmission. Other examples are replacing steel by plastics automobile construction, or using thinner sheets of higher-strength alloys replace thicker sheets of conventional steel. In the US, the share of bas materials in the GNP has decreased by almost 30 per cent since 1970.

Fuel intensity measures how much energy is needed to manufacture given product: for example, the fuel per ton of steel, or the electricity per kil gram of polyethylene. Table 6.4 gives typical energy-intensity forecasts f some basic materials made in the past decade and the actual improvemen In most cases, forecasts were surpassed.

Table 6.4 *Forecasts for fuel-intensity improvement (% per year)*

Industry	*NAS (1990)*	*NAS (1979)*	*DOE (1989)*	*OTA (1983)*	*Actual improvement*
Steel	1.0	0.9	2.4	2.3	2.1
Chemicals	1.5	1.7	0.7	0.6	3.4
Paper	2.2	1.3	2.1	1.3	4.7
Petroleum	0.5	na	0.9	0.6	2.5

Source: Hollander, J M (ed), *The Energy–Environment Connection*, Island Press, Washington DC, US (1992).

Recycling broadens the concept of dematerialization and, if pushed to its limits, would contribute effectively to a decrease in pollution although, in a number of cases, it is not cost effective. Table 6.5 shows that the energy needed to recycle a few basic materials is lower than that required to produce it from raw materials.

Table 6.5 *Energy spent in recycling (BTU/pound)*

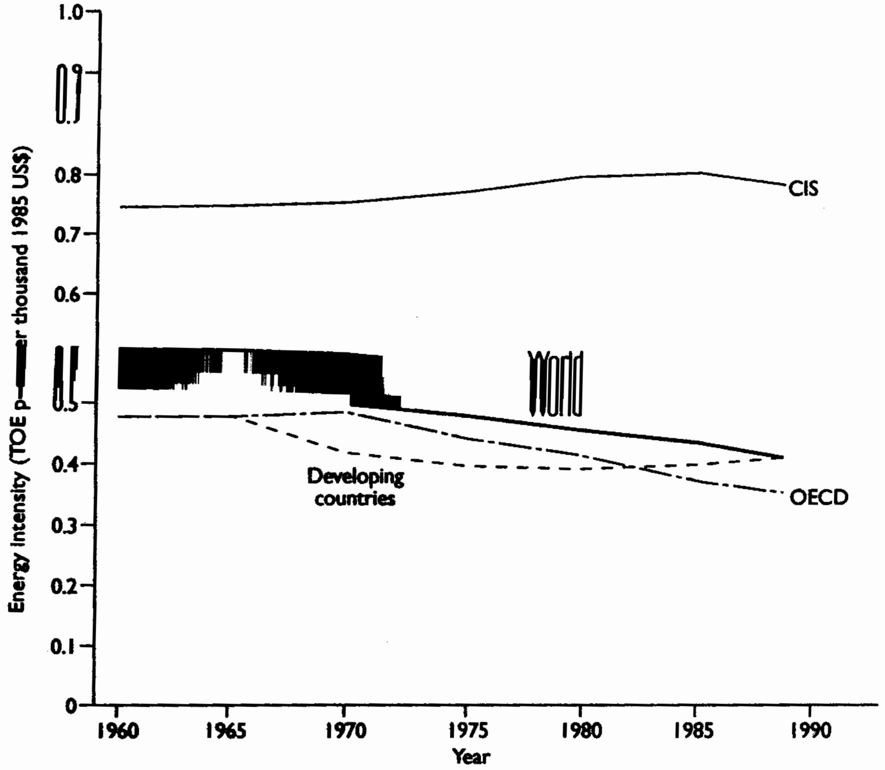
Source	*Glass*	*Steel*	*Plastic*	*Aluminum*
Made from raw materials	6,500	35,000	35,000	100,000
Made from recycled materials	4,500	15,000	15,000	25,000

Source: Hollander, J M (ed), *The Energy–Environment Connection*, Island Press, Washington DC, US (1992).

Aluminum is the leader in container recycling since recycling takes only one-quarter of the energy to make it from raw material. For glass, this figure is much less attractive. Automobile hulk recycling approaches 95 per cent, for example, because the mass is large enough to repay the effort. In contrast, recycling of plastics is only in the range of 1 to 2 per cent, largely because the individual pieces are small and hard to sort.

The challenge is to create other systems that use recycled materials in high-value applications, such as recycling old plastic bottles into new ones.

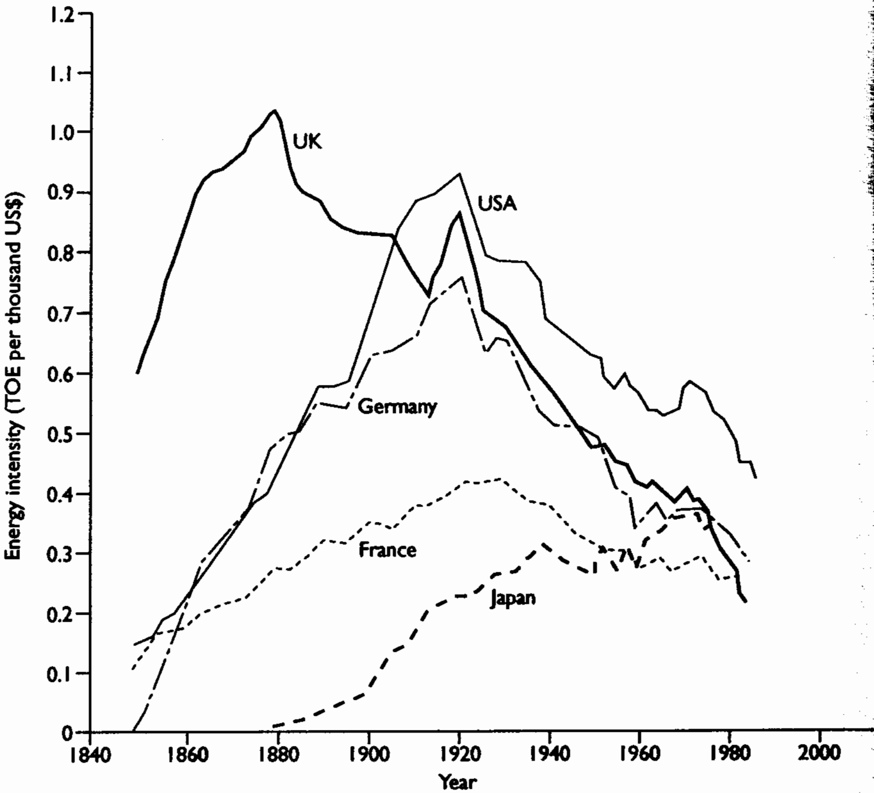
Particularly after the oil crisis in the 1970s, industrialized countries successfully reduced their consumption of fossil fuels through improvements in the efficiency of energy use and the structural changes that led to post-industrial economies. This is, of course, also due to 'saturation effects' in the consumption of certain goods. As a result of a combination of these factors, the energy intensity of OECD countries has been *falling* by about 2.3 per cent a year during the past few decades, although it is still *growing* in the developing countries at a rate of approximately 1.2 per cent per year (Figure 6.3).



Note: CIS – Commonwealth of Independent States (former Soviet Union).
Source: *Survey of Energy Resources*, World Energy Council, London, UK (1989).

Figure 6.3 Energy intensity evolution of different regions

For some industrialized countries, such as UK, US, Germany, France and Japan, data are available that permit the construction of curves of the historical evolution of the energy intensity over more than a century, with the well-known result that the energy intensity increased as the infrastructure and heavy industry developed, going through a peak and then a steady decline. Latecomers in the industrialization process, such as Japan, peaked at lower energy intensities than their predecessors, indicating early adoption of innovative and modern, more energy-efficient industrial processes and technologies (Figure 6.4).



Source: Martin, J M, 'L'intensité énergétique de l'activité économique: les évolutions de très longues périodes livrent-elles des enseignements utiles?', *Economie et Sociétés*, 49, 27 (1988).

Figure 6.4 Long-term historical evolution of the energy intensity of industrialized countries

For developing countries, data are available only for the past few decades and there are two methodological problems that limit their usefulness:

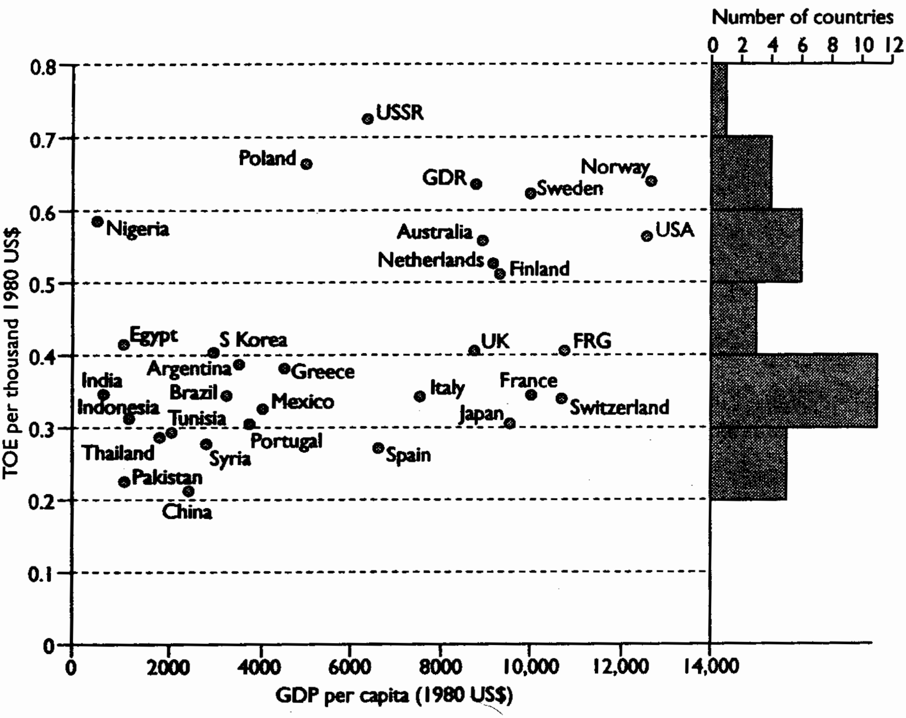
- The contribution of non-commercial energy is rather significant in a number of countries and not very well known since, by its very nature, it is not the object of commercial transactions. Adding non-commercial energy would give a better measure of all energy consumed but will not take into account the fact that the end-use efficiency of non-commercial sources is usually lower than that for commercial sources, leading to energy intensities higher than they should be. Except for the very poor countries where non-commercial energy consumption is dominant, this does not seem, however, to be a very serious problem.

- The calculation of GDP using official US dollar rates of conversion or their purchasing power parity (ppp) value can make a considerable difference: in some cases the GDP in ppp US dollars can be three or four times larger than the GDP in US dollars.

In the most comprehensive analysis available, Nielsson has plotted the energy intensities for 31 countries (developed and developing) for the period 1950 to 1988 using ppp US dollars for the GDP and commercial plus non-commercial primary energy using United Nation's tables. His results indicate that:

- The energy intensities of most of the industrialized countries are decreasing.
- The energy intensities of developing countries are increasing and, in general, are smaller than in industrialized countries.

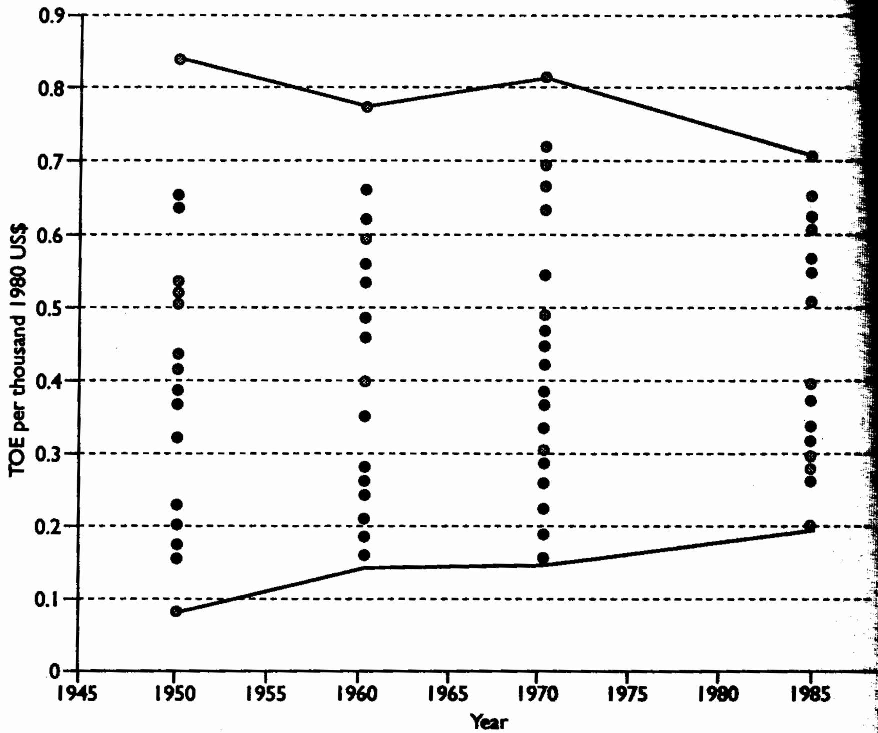
A plot of Nielsson's data for the energy intensities for 1985 is shown in Figure 6.5 and the histogram shows that values of energy intensity cluster around an average value of 0.4 TOE/US$ 1000.



Source: Nielsson, L, 'Energy Intensity in 31 Industrialised and Developing Countries, 1950–1988', *Energy*, 18, (4), 309–322 (1993).

Figure 6.5 Energy intensity for 31 countries (1985)

Figure 6.6 indicates how the values of the energy intensities for the countries have evolved from 1950 to 1985. The clustering around an av value became more marked as time evolved, indicating that energy sys around the world have important commonalities. This is not very surp as far as industrialized countries are concerned. For developing countri indicates that the modern sector dominates economic activity and en consumption, both of which are similar to those of industrialized count



Source: Nielsson, L, 'Energy Intensity in 31 Industrialised and Developing Countries, 1950–1988', *Energy*, 18 (4), 309–322 (1993).

Figure 6.6 Evolution of energy intensity for 31 countries (1950–1985)

Technological 'leapfrogging' and technology transfer

Because of their rapid growth of energy consumption, LDCs are important theaters for innovation, especially in the energy-intensive basic materials industries (steel, chemicals, cement, etc) for which demand has almost reached saturation in the industrialized countries. It is for the same reason that it is so important that modern technologies should be incorporated early into the process of development, by 'leapfrogging' the traditional path of development, and not being retrofitted as was the case in industrialized countries.

This process is already taking place, as demonstrated by the amazing speed of adoption and diffusion of innovative and state-of-the-art technologies in developing countries. An example can be seen in Indian villages where lighting is provided by fluorescent lamps instead of old, inefficient incandescent light bulbs. Other less spectacular technologies, such as communal biogas plants, can serve several purposes such as power for lighting, water pumping, fertilizer production and sewage treatment. Black-and-white television is becoming a thing of the past even in the remote areas of Amazonia. The same has happened with cellular telephones which have bypassed wire-connected telephones in many places.

Despite its attractiveness, 'leapfrogging' should not be regarded as a universal strategy, because sometimes the products or technologies needed are not available in developed countries, or are not well suited to the developing country needs, for the following reasons:

- In developing countries there is usually the need to strike a balance between relative prices of labor and capital. Because labor is expensive and capital is relatively cheap in industrialized countries, many innovative technologies produced there are labor-saving and capital-intensive. On the other hand, since labor is cheap and capital expensive in developing countries, there is a need for more labor-intensive, capital-saving advanced technologies.
- Developing countries need innovations better suited to their natural resource endowments than those they can obtain from industrialized countries. For example, not only is the production of biomass labor-intensive, it is also more readily available than fossil fuels in most tropical countries, for example, India, Brazil and Indonesia. Hence it is a major source of energy in such countries.

R&D priority for developing countries should be to find ways to improve the efficiency of using biomass for energy and transforming the resource from being 'the poor man's oil' into electricity and fluid fuels that are considered attractive in modern energy markets.

Experience shows that the transfer of technology from industrialized to developing countries depends on the fulfillment of the following conditions:

- Availability of adequate technology in industrialized countries, absence of commercial conflicts and the possibility of making good business deals for both partners (for example, fluorescent lighting in India or Brazil).
- The existence of legislation in developing countries that guarantees remuneration for patent rights, as well as the necessary local infrastructure to permit the transfer and absorption of the technology.
- Firm government decisions to implement policies that might require expenditure in specific areas conducive to technological 'leapfrogging'. This can be done, for example, by setting rules for national development banks to encourage them to finance preferentially projects that incorporate advanced technologies.

The 'Decarbonization' of the Global Economy

The above concepts on the dematerialization and reduction of the fuel i sity of the economy can also be used to analyze the reduction of g carbon emissions (and other pollutants) associated with fossil fuel co tion. We start with the four variables:

- carbon emissions (C);
- energy consumption (E);
- economy (as measured by GDP); and
- population (P),

and the identity:

$$C = (C/E) \times (E/GDP) \times (GDP)$$

or

$$C = (C/E) \times (E/GDP) \times (GDP/P) \times (P)$$

$E/GDP = I$ is the energy intensity (energy needed to produce one uni GDP measured usually in TOE per US$ 1000 of GDP); C/E is the index 'carbonization' of the economy (measured usually in tons of carbon p TOE); GDP/P is the GDP per capita, and P is the population.

The rate of increase of carbon emissions ($\Delta C/C$) is, therefore, given a sum of four factors:

$$\Delta C/C = \Delta(C/E)/(C/E) + \Delta(E/GDP)/(E/GDP) + \Delta P/P + \Delta(GDP/P)/(GDP/P)$$

Similar equations can be established for other pollutants.

An analysis of trends of the past indicates that:

- 'Decarbonization' of the world economy is *decreasing* at the rate of 0.3 p cent per year, $\Delta(C/E)/(C/E) = -0.3$ per cent per year (see Figure 6.7).
- The energy intensity of the world economy is *decreasing* at a rate o approximately 2 per cent per year: $\Delta(E/(GDP))/(E/(GDP)) = -2$ per ce per year. WEC scenario C requires a 2.4 per cent per year decrease of th world's energy consumption.
- GDP is *increasing* at a rate of 3.2 per cent per year: $\Delta(GDP)/(GDP) = +3.2$ per cent per year. This is due to a population increase of 2 per cent per year: $\Delta P/P = +2$ per cent per year (see Box on Population growth) and a per capita GDP *increase* $\Delta(GDP/P)/(GDP/P)$ of 1.2 per cent per year.

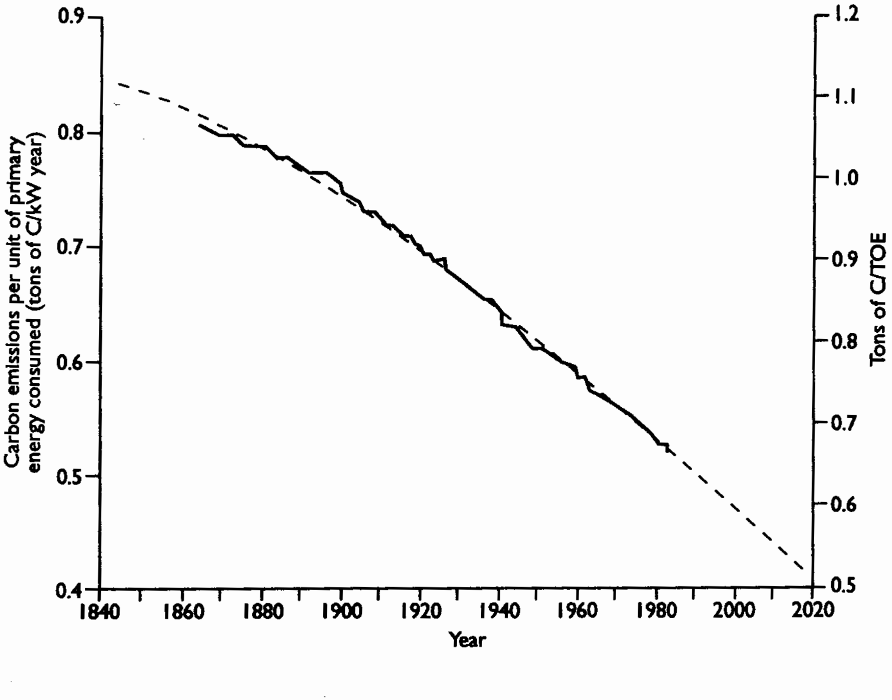
Thus,

$$\Delta C/C = -0.3 - 2 + 2.0 + 1.2 = 0.9 \text{ per cent per year}$$

Carbon emissions are increasing by 0.9 per cent per year. To stabilize current emissions, ie to have $\Delta C/C = 0$ the following would be necessary:

- reduce population growth from 2 to 1.1 per cent per year; or
- reduce per capita income from 1.2 to 0.3 per cent per year; or

- increase the rate of decarbonization from –0.3 to –1.2 per cent per year; or
- reduce the rate of decrease of the energy intensity from –2.0 to –2.9 per cent per year.



Source: Nakicenovic, N et al, 'Long-Term Strategies for Mitigating Global Warming' *Energy Policy*, 18 (J), 401–609 (1991).

Figure 6.7 'Decarbonization' of the world economy

Population growth

Standard projections indicate that the population of the developing world should reach 8.6 billion in the year 2050 and 10.2 billion in the year 2100. Population growth, as seen above, is one of the main factors determining energy consumption in the next few decades; it is, therefore, important to list the factors that could determine reductions in this growth. According to Bongaarts, the causes of population growth are:

- unwanted pregnancies;
- desire for large family size; and
- population momentum (which is a consequence of a young population age structure).

Bongaarts has estimated the contribution of these factors in the future population size with the results indicated in Figure 6.8.

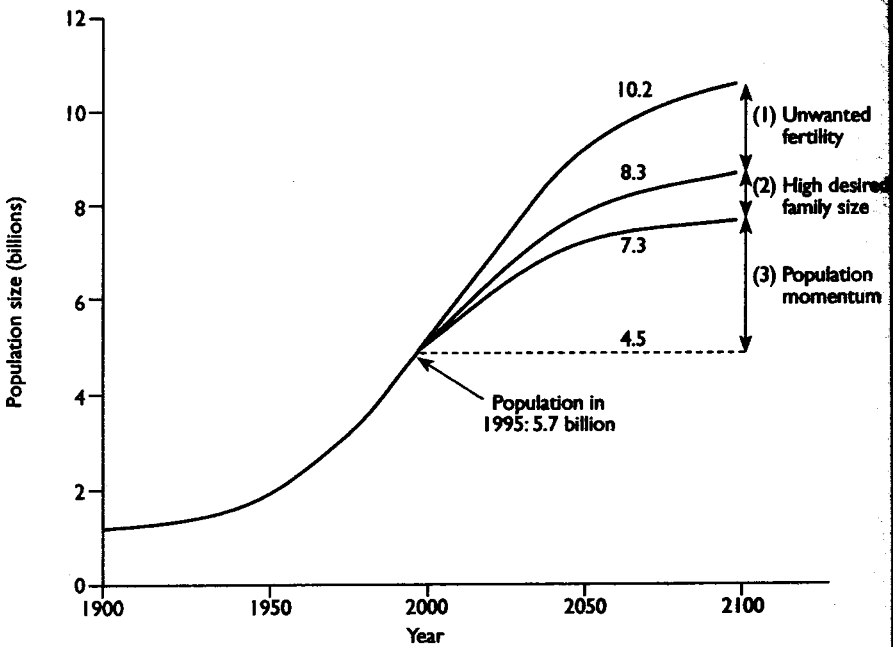


Figure 6.8 Causes of population growth

Reducing unwanted pregnancies by strengthening family planning programs could reduce the population by the year 2100 from 10.2 to 8.3 billion.

Reducing the demand for large families through investments in human development could lead to a further reduction from 8.3 to 7.3 billion by the year 2100.

The population momentum could be slowed down if the average childbearing age of women was raised. A further reduction from 7.3 to 6.1 billion by the year 2100 could be achieved by increasing the average age of childbearing by five years. All such reductions are theoretical upper limits of what could be achieved, but they point out the possibilities of action to bring about a real reduction in population growth in the next century.

As is well known, the developed countries experienced 'demographic transitions' in the past which have led to the present situation where the 'total fertility rate' (TFR) has fallen to approximately two, which is the replacement rate. The precise causes for the decline of TFR are very complex and synergetic in nature, including those listed above. The developing countries can be expected to follow a similar trend.

Source: Bongaarts, J, 'Population Policy Options in the Developing World', *Science*, 263, 771–776 (1994).