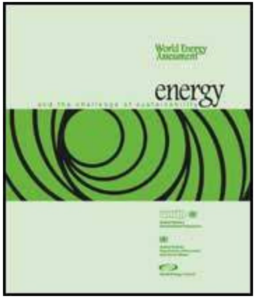

World Energy Assessment - Energy and the Challenge of Sustainability (UNDESA - UNDP - WEA - WEC, 2000, 517 p.)

Encouraging greater international cooperation
Annex: Trends in research and development funding

World Energy Assessment - Energy and the Challenge of Sustainability (UNDESA - UNDP - WEA - WEC, 2000, 517 p.)

PART IV. WHERE DO WE GO FROM HERE?

Chapter 11. Energy and Economic Prosperity

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ABSTRACT

Energy demand in developing countries will rise enormously as per capita incomes and populations grow. By reference to the situations of people without access to modern energy forms, the chapter shows why energy is an economic 'good', and thus why energy supplies will need to be expanded to meet emerging demands if living standards are to be improved and developing countries are to achieve prosperity. Energy demand in industrialised countries is also likely to remain strong, notwithstanding - and to some extent, because of - continuing gains in the efficiency with which energy is produced and used. Both energy resources and financial resources are amply available to meet market needs.

But will solving the 'pollution problem' from energy use prove too costly from an economic perspective? There is no evidence that it will, and most assessments point to the likelihood of an improvement, not a deterioration, in economic prospects with enlightened environmental policies. Technologies are now available for addressing the most serious forms of local and regional pollution from fossil fuel use, at costs

that are small relative to the costs of energy supplies. So there is every reason to be sanguine in this respect. In fact, developing countries are in a position to address their local and regional pollution problems at a far earlier phase of development than were the industrialised countries before them - within the first third of this century if they wish. Furthermore, there are highly promising options for addressing global warming in the long term - renewable energy, hydrogen-related technologies and fuel cells, for example - which could be developed through enlightened research, development, and demonstration policies.

Much therefore will depend on energy and environmental policies. In reviewing the ground rules for such policies, the chapter shows that the aims of developing countries for achieving economic prosperity and of industrialised countries for improving theirs are fully consistent with those of simultaneously meeting rising world energy demand and realising a low-pollution future.

Despite rising energy taxes, demand-side interventions, and supply shortages in many countries, world consumption of commercial energy continues to rise. The increase averages 1.5 percent a year, or 150-200 million tonnes of oil equivalent energy (6.5-8.5 exajoules) a year - an amount equivalent to two-thirds of the annual energy consumption in France or the United Kingdom. Developing countries in Asia, Latin America, the Middle East, and Africa account for most of this growth (table 11.1). In North America, Europe, and Japan energy markets have matured and aggregate growth is low; in the transition economies of the former Soviet Union and Central and Eastern Europe consumption has declined substantially with economic recession and restructuring.

The reasons for the rapid growth of consumption in developing regions are well known. Income elasticities of demand for energy are high, and as per capita incomes

grow people want their energy needs met - just as people in industrialised countries did before them. Nearly 2 billion people are without access to modern energy forms such as electricity and gas, while average consumption levels of the 2 billion people who do have access are barely one-fifth of those in the economies of the Organisation for Economic Cooperation and Development (OECD). With population growth, perhaps as many as 6 billion more people will require access to modern forms of energy over the next half century. With successful economic growth - and especially with catch-up in the developing regions - world economic product is set to rise 10-fold or more this century, much as it did in the industrialised countries in the last century. Large increases in world energy demand thus lie ahead in any scenario of economic success. (For further details see the scenarios for the growth of populations, economic output, and energy use in chapter 9.)

TABLE 11.1. PRIMARY ENERGY CONSUMPTION BY REGION, 1987 AND 1997 (EXAJOULES)

Region	1987	1997	Total increase	Annual percentage increase
United States and Canada	86	101	15	1.7
Europe	74	76	2	0.2
Former Soviet Union	58	38	- 20	- 4.1
South and Central America (including Mexico)	15	20	5	3.4
Middle East	10	15	5	4.6
Africa	8	11	3	3.0
Asia and Pacific (including Japan)	64	101	37	4.8

Total	**315**	**362**	**47**	**1.5**

Note: Converted at the rate of 1 billion tonne of oil equivalent energy = 43.2 exajoules.

Source: BP, 1998.

Modern energy forms are often viewed as economic 'bads'. In fact, they are an economic good, capable of improving the living standards of billions of people.

This chapter provides an economic perspective on the questions posed by the prospective increases in consumption:

- **How important is meeting emerging energy demand to the achievement of economic prosperity in all regions of the world in this century? What of the 2 billion people still without access and the demands of new populations - how are their demands to be met, and what would be the economic and environmental consequences of failing to meet them?**

- **What will be the impact on economic growth of meeting the environmental challenges discussed in chapter 3?**

- **How, and under what conditions, will market liberalisation, the changing role of government, and globalisation of the energy industry - all inter-related**

developments - help to meet the challenges of achieving energy market growth, extending services to unserved populations, and solving the environmental problem?

- **Modern energy forms are often viewed ad economic 'bads.' In fact, they are an economic good, capable of improving the living standards of billions of people.**

Energy consumption and economic well-being

Notwithstanding the historical importance of modern energy forms in raising economic output, they are often viewed as economic 'bads' not 'goods' - a view that has gathered force in recent years and is the source of much confusion in energy and environmental policies. In some countries energy use is under attack not only from environmental groups but also from finance ministries who see high energy taxes as a means of simultaneously raising revenues (which of course they do) and reducing pollution (at most a secondary effect).

In fact, modern energy forms are an economic good, capable of improving the living standards of billions of people, most of all the billions of people in developing countries who lack access to service or whose consumption levels are far below those of people in industrialised countries. It is the pollution arising from energy production and use that is the economic bad, not energy use itself.[1] This distinction, however elementary, is not trivial. Technologies are available, emerging, or capable of being developed that can solve the pollution problem at a small fraction of the overall costs of energy supplies. The more policies recognise the distinction, the more likely will we be able to meet rising world energy demands with greatly reduced pollution. Furthermore, once the benefits of pollution abatement are taken into account,

economic output and well-being are likely to be higher not lower.

No country has been able to raise per capita incomes from low levels without increasing its use of commercial energy. In industrialised countries demand for fossil fuels has expanded more than 50-fold (in energy units) since 1860. Horsepower per worker in industry and agriculture has grown commensurately and contributed to enormous increases in labour productivity. Cross-sectional data show unequivocal correlations between the use of energy and power and the quality of life (see figure 1 and table 1 in the overview). A similar pattern is evident in comparisons of per capita consumption levels of commercial energy in selected developing countries with those in industrialised countries (table 11.2).

TABLE 11.2. PER CAPITA INCOMES AND CONSUMPTION OF COMMERCIAL ENERGY FOR SELECTED DEVELOPING AND INDUSTRIALISED COUNTRIES, MID-1990S

Country	Per capita income, 1995	Per capita consumption of commercial energy, 1994 (gigajoules)[a]
India	340	10
Ghana	390	4
China	620	28
Egypt	790	25
Brazil	3,640	30
Korea, Rep. of	9,700	125
United	18,700	158

United States	26,980	327
Germany	27,510	173

a. Converted at the rate of 1 kilogram of oil equivalent = 0.0418 gigajoules.

Source: World Bank, 1997.

These are, of course, simple correlations that leave open the questions of how much energy actually contributes to economic well-being and how much energy per person is needed to achieve a satisfactory standard of living. These questions are considered below, first with reference to people without access to modern energy supplies in developing countries today and then to people in industrialised countries before modern energy supplies were widely available.

The transition from traditional to modern energy sources

Alongside the nearly 2 billion people in developing countries who lack access to electricity and modern fuels[2] are some 1.3 billion people - more than twice the populations of the United States and the European Union combined - who were newly served with electricity during 1970-95. Large regions of the developing world are not standing still, and technical progress is making the transition from traditional to modern fuels possible at a much earlier phase of development than was the case for industrialised countries. In the United States the transition from 90 percent dependence on wood fuels to virtually none took 70 years (1850-1920), by which time average per capita income was nearly $5,000 (in 1997 prices).[3] In the Republic of Korea the transition was substantially complete by 1980, when average per capita

income was about $3,000. For developing countries today the transition to modern fuels tends to be nearly complete when per capita incomes are in the range $1,000-2,000 (World Bank, 1996; figure 11.1).

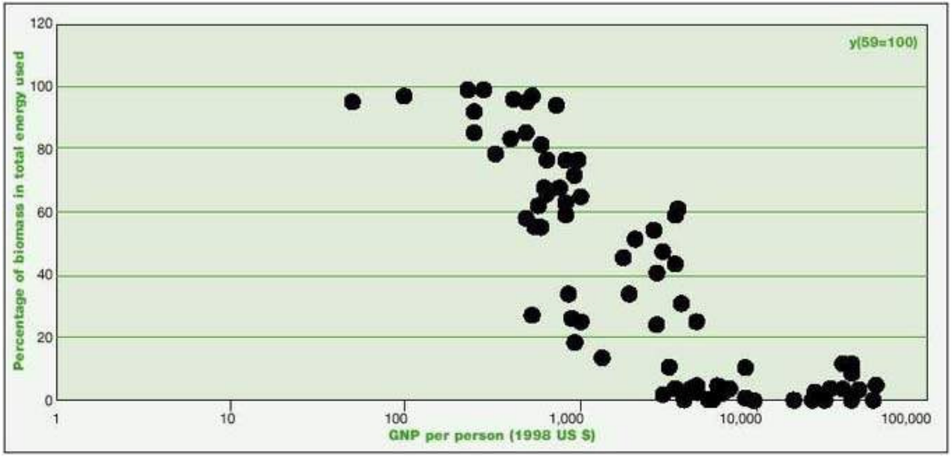


FIGURE 11.1. USE OF BIOMASS AS A COOKING FUEL RELATIVE TO GNP PER CAPITA IN 80 COUNTRIES

Source: World Bank, 1996.

Technical progress and lower costs. Why is this transition taking place at lower incomes? The main reasons are that modern energy forms are more abundant and the costs of energy are much lower than they were when today's industrialised countries were making the transition. Electricity was not available a century ago, when per capita incomes in the now-industrialised countries were five times those in South Asia and Sub-Saharan Africa today. When electrification began, the costs, at $1.7 a kilowatt

per hour (in 1997 prices), were 20 times today's costs (World Bank, 1992). Natural gas and liquefied petroleum gas (LPG) were also unavailable. Lebergott (1993, pp. 106-107) notes that, notwithstanding the massive increase in energy consumption in the United States in the 20th century, as families began to heat and later to cool every room in the house, U.S. consumers spent no more on heating and cooling their homes in 1990 than they did in 1900: "Despite all the factors driving up expenditures for fuel, ... they actually spent less than 3 percent [of their incomes] - compared to 3 percent in 1900. The explanation? Persistent productivity advance by businesses that mined fuel and produced electricity". These productivity advances were made possible, in part, by public policies that permitted the energy companies and utilities to earn good returns on their investments (this point is developed further in the section on liberalisation and globalisation).

The importance of per capita income growth. Although modern energy forms contribute appreciably to economic welfare, they are not affordable until incomes rise above a certain threshold (see figure 11.1). Technical progress and falling costs are lowering this threshold, but ultimately income growth is what matters. Countries that have been able to raise productivity and incomes on a broad basis - through good macroeconomic management, trade, and investment in human and physical resources - have been able to extend service most rapidly.

The benefits of service extension

At the same time, improving access to modern energy forms yields appreciable economic and health benefits.

Savings in time and labour in the home. As the World Bank's (1996) report on rural energy and development noted, when wood fuels are scarce, the time people spend

collecting fuel is time they cannot devote to productive activities. Recent surveys in Nepal show that women spend up to 2.5 hours a day collecting fuel wood and fodder in areas where wood fuels are scarce.

The saving in time and labour, however, extends far beyond the saving arising from the displacement of fuel wood. It includes the economic convenience of modern energy forms and the advances they make possible, including hot and running water, washing machines, refrigeration, food and crop processing, extension of the day through electric lighting, and an array and diversity of other uses in homes, industry, and commerce too numerous to list here. Table 11.3 illustrates this point with a few comparative statistics for a developing and an industrialised country. Lebergott (1993, p. 112) comments:

> **From 1620 to 1920, the American washing machine was a housewife. As late as 1920 the family laundry took about seven hours a week. The typical housewife washed some 40,000 diapers for her four children.[4] Lacking running water, she carried 9,000 gallons [40 tons] of water into the house each year, then boiled most of it. And she relied on a scrub board, not a washing machine.**

The heavy reliance on family labour to provide for the most basic of energy needs - for cooking food and, in many climates, keeping the family warm - is an immense opportunity cost to the family. When used for pumping, modern energy forms also improve access to water. In developing countries today a family of six people consuming 30 litres of water per person per day (a low level of consumption, about one-fifth to one-tenth of that consumed in industrialised countries) will fetch and carry by hand around 35 tons of water a year from wells and hand-pumps, often over appreciable distances.[5] Surveys of low income families consistently reveal the

economic importance of the saving in family labour made possible by substituting fossil for wood fuels and of the contribution modern energy forms may make, among other things, to improving access to water.[6]

Reductions in pollution and improvements in health. The switch to modern fuels reduces the level of indoor pollution by several orders of magnitude, eliminating a major health risk now afflicting billions of people (see chapter 3). A study of air pollution in developing countries found air pollution levels from biomass combustion at several multiples of the World Trade Organisation (WHO) peak guidelines: 6 times greater for Zimbabwe, 11 times for China, 5 to 34 times for Kenya (daily average), 9 to 38 times for Nepal, 1 to 39 times for Papua New Guinea, and 16 to 90 times for India (a 15 minute peak) (Smith 1988). Fitting stoves with flues lowers pollution levels to well within WHO guidelines and leads to considerable gains in efficiency as well.

TABLE 11.3. APPLIANCE USE IN HOUSEHOLDS WITH ELECTRICITY IN INDONESIA AND THE UNITED STATES, 1987 (PERCENTAGE OF HOUSEHOLDS)

Appliance	Indonesia (low-income households)	U.S. households
Lighting	100	100
Television	31	100
Irons	21	-
Refrigerator	1	100
Washing machine	-	73
Air conditioning	0	62

- Not available.

Source: World Bank, 1996, and Lebergott, 1993.

TABLE 11.4. POPULATIONS SIZE AND ESTIMATED PER CAPITA CONSUMPTION OF COMMERCIAL ENERGY BY COUNTRY GROUP, 1998

Energy form and country group	Estimated commercial energy consumption	Population (millions)
Primary energy	gigajoules per person	
• OECD	230	900
• Countries of the former Soviet Union	125	300
• Developing countries	23	4,800
Peak electricity demand	killowatt hours per person	
• OECD	1.8	900
• Countries of the former Soviet Union	0.9	300
• Developing countries	0.2	4,800

Note: Consumption estimates are based on statistics for 1992 and OED projections, assuming a 55 percent load factor for electricity demands. Population estimates are based on World Bank projections from 1992.

Source: OECD, 1995, for consumption; World Bank, 1992, for population.

Reductions in environmental damage. The transition to modern fuels *reduces* pressures on forests and land, and thus on watersheds and groundwater resources and even on biodiversity. The dangers of flash flooding are also reduced. By some estimates the consumption of wood, crop residues, and animal dung for cooking fuels amounts to 1,000 million tons of oil equivalent energy a year, more than three times the coal mined in Europe in a single year and twice that mined in the United States and China in a year (World Bank, 1996). The same amount of useful heat could be produced with only 100 million tons of LPG (in oil equivalent units) or 200 million tons of kerosene, which is equal to only 3 percent of world oil and gas consumption.

Gains in energy efficiency. Thus the transition to modern fuels can lead to large gains in energy efficiency. LPG and kerosene are just two woodfuel substitutes that result in large efficiency gains. The use of biogas from agricultural residues leads to similarly large gains. It is not surprising, therefore, though the point is often overlooked, that a rise in commercial energy use among the poorest people in the world *reduces* their energy demand, a pattern that continues until incomes reach quite high levels - in the case of Brazil, for example, to somewhere between 2 and 5 times the minimum wage (see figure 3 in the overview; chapter 10 provides further data on the efficiency of the alternative fuels for cooking).

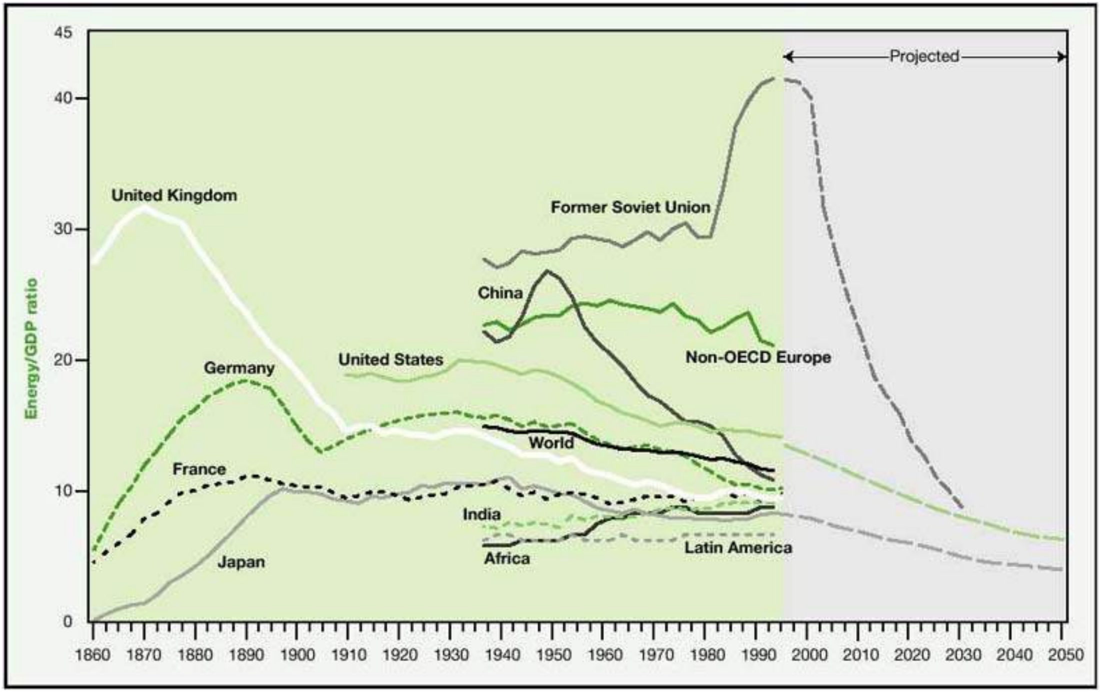


FIGURE 11.2. RATIO OF ENERGY CONSUMPTION TO GDP FOR SELECTED COUNTRIES AND REGIONS, 1860-1996, AND PROJECTIONS

Note: Energy consumption is measured in megajoules; GDP in 1990 U.S. dollars in purchasing power parity. Pre-1961 GDP calculations are based on exchange rates. Energy data exclude energy from biomass.

Source: IEA, 1997, 1998; CEC 1996; Chandler, and others, 1990; ISI 1999

Energy use forecasts and energy efficiency

In light of the contribution of modern energy forms to higher incomes and greater economic well-being, the expansion of supplies should be welcomed from both economic and commercial viewpoints. Energy markets are potentially very large and are set to grow for most of the century. Recall that per capita consumption levels of commercial energy and electricity in developing countries are barely one-tenth of those in OECD countries, while their populations are over five times larger (table 11.4). The energy scenarios presented in chapter 9 point to an increase in the world's consumption of commercial energy over this century of roughly 2.5 to 5 times today's levels.

Forecasts of long-term energy demands vary considerably with assumptions about the growth of per capita incomes and populations.[7] They also vary with assumptions about future gains in energy efficiency. The assumptions about energy efficiency gains warrant further discussion because of their impact on assessments of the amount of energy required to support economic production and provide for people's energy needs.

It has been widely observed that the energy intensity of an economy (the ratio of energy consumption to GDP) rises during the early and middle phases of economic development, when the industrialisation and 'motorisation' of economies are strong, and then peaks and declines as the less energy-intensive service sector begins to occupy a larger share of economic activity (figure 11.2).[8] The later a country industrialises, the lower its peak energy intensity because of intervening improvements in the efficiency of energy conversion processes - especially for electricity generation - and energy use. This pattern has held for more than a century,

as a comparison of the experiences of the United Kingdom, Germany, the United States, France, and Japan shows (see figure 11.2). Developing regions are exhibiting the same pattern. (Exceptions are economies in transition, which have experienced abnormally high energy intensities historically, but which are now expected to decline with new investment and gains in energy efficiency.) A number of engineering and economic studies have shown that the possibilities for further gains in energy efficiency are far from exhausted, such that we can expect a continual lowering of the peak intensity as more countries become developed.[9]

Such improvements in energy efficiency mean that developing countries are likely to need less energy to produce a unit of GNP and to meet consumer needs per unit of income than was the case for the industrialised countries. How much less is controversial, because of ambiguities in the evidence and oversimplifications in both the engineering and economic models of energy consumption. However, no empirically based study has shown that developing countries can achieve prosperity without very large increases in demand for energy, even with strong assumptions about improvements in energy efficiency.

Ambiguities in the evidence and shortcomings in methods

Another perspective on the links between income growth and energy consumption is provided by economic estimates of income elasticities of energy demand. These show a rising trend as per capita income grows from very low levels and then a declining trend at high income levels (table 11.5). The income effect is weak among the most impoverished people in the world - whose main initial demands, as incomes begin to rise, are for meeting such basic needs as food, safe water, and improved health services - but becomes very strong as incomes rise above a certain threshold. Recall figure 11.1, which shows that once income moves into the $1,000 - $2,000 range,

substitution from biofuels to modern energy proceeds as rapidly as income growth permits. The income effect is also strong in the industrialisation phase of development, but it then begins to decline as markets mature, falling to a low value at high income levels, such as those of the OECD economies in the 1970s and 1980s.

An intriguing estimation result in table 11.5 is the *negative* per capita income elasticity in the highest income range. Judson, Schmalensee, and Stoker (1999) caution that this estimate may not be statistically significant, commenting that it is "more likely to reflect some sort of isolated measurement problem than a real economic phenomenon. We are on balance fairly confident that beyond per capita incomes of $1,500 or so (in 1985 dollars), there is a tendency of the economy-wide income elasticity of demand for energy to fall with per-capita income, but the evidence for a negative income elasticity at high income levels is, in this sample, less than compelling".

Yet engineering studies also point to the possibility of a decline in energy demand per capita at high income levels even as per capita incomes increase. As energy markets become satiated at high income levels, long-term improvements in the efficiency of energy use may more than offset any further increases in demand arising from income growth.[10] The effects are complex, and it is not surprising that the study by Judson, Schmalenensee, and Stoker (1999) is inconclusive. Economic models have so far not been able to capture the effects in a satisfactory way.

TABLE 11.5. VARIATION IN PER CAPITA INCOME ELASTICITIES OF DEMAND FOR COMMERCIAL ENERGY WITH PER CAPITA INCOMES

Income (1985 U.S. dollars in purchasing power parity)	Income elasticity
= 823	0.219

823-1430	1.098
1,430-2,545	1.400
2,545-4,249	0.784
4,249-8,759	0.394
= 8,759	- 0.312

Source: Judson, Schmalensee, and Stoker, 1999.

There are five effects on energy demand that need to be considered: income, price, population, energy efficiency as a means of *reducing* energy demand for a particular purpose, and energy efficiency as a means of reducing the price of energy and thereby *raising* energy demand (sometimes called the rebound effect). These effects can be summed up in the simplified model of energy demand growth:

$$e = \gamma . g - \beta . p\{x\} - x + n$$

where e is growth of per capita energy demand; g is growth of per capita income; p is growth of prices; n is population growth; x is the growth of what is sometimes called the autonomous energy efficiency index; γ is the income elasticity of demand for energy; and β is the numerical value of the price elasticity. The notation p{x} summarises the fifth effect, of price as a function of - and generally declining with - energy efficiency.

Most energy demand studies using econometric techniques have not attempted to estimate x, the rate of improvement in the autonomous energy efficiency index. The review by Grubb and others (1993, p.453) sums up the uncertainties. First they note the wide range - from less than 0.5 percent to more than 1.5 percent a year - in x.

They then add:

> **We cannot suggest a definite value for this parameter, but it is important to understand it. The parameter has been badly misnamed: it is a measure of all non-price-induced changes in gross energy-intensity - which may be neither autonomous nor concern energy efficiency alone. It is not simply a measure of technical progress, for it conflates at least three different factors. One indeed is *technical developments....* another is *structural change,* i.e., shifts in the mix of economic activities.... The third is *policy-driven uptake of more efficient technologies*.... [Emphasis in original.]**

Compounded over a century, the 1 percentage point difference in estimates of the autonomous energy efficiency index results in a 2.7-fold difference in energy demand projections and helps to explain the large differences in the scenarios of energy demand developed in chapter 9.

Energy efficiency as a beneficial stimulus to energy use

Environmental studies frequently argue for improvements in energy efficiency as a means of reducing environmental damage. There are, however, two dangers in placing too much reliance on this argument. One is that improving energy efficiency, by lowering costs and prices, may also increase demand (the rebound effect noted above).[11] The second is that the argument neglects an important economic benefit of energy efficiency: it makes energy more affordable and accessible to consumers, which is especially important today for developing countries.[12]

Per capita consumption levels of

commercial energy and electricity in developing countries are barely one-tenth of those in OECD countries.

Consider the following examples. The efficiency of motive power rose from less than 1 percent for the early steam engines of Newcomen and Smeaton in the 18th century and 5 percent with the invention of the stream condenser by Watt later in the century to 20 percent for gasoline and diesel engines and 40 percent for electric motors today (after allowing for losses in electric power stations). This was a 40-fold increase over two centuries. It is conceivable that without such efficiency improvements the industrial revolution - and the unprecedented increase it brought about in per capita incomes in the industrial economies in the past two centuries - might not have taken place.

Or consider lighting. The efficiency in lumens per watt rose 20-fold following the displacement of kerosene by electric incandescent lamps and then another 5-fold with the invention of fluorescent lamps in the 1930s. These improvements help explain the massive growth in commercial lighting over the past half century. Another socially important example, mentioned earlier, is the contribution of modern fuels to the efficiency of cooking and heating devices in the homes. These were a primary cause of the movement away from traditional fuels and of improvements in the economic well-being of billions of people.

To take a final example, the conversion efficiency of power stations fired by fossil fuels rose from around 3 percent at the beginning of the 20th century to more than 50 percent for combined-cycle gas-fired power stations today (Anderson, 1993). This improvement has contributed to a 20-fold drop in the costs of electricity since 1900, stimulated industrial expansion, and brought the benefits of electricity consumption to

more than 3 billion people in the world today. Numerous other examples could be cited, from commercial heating (insulation, heat pumps, double glazing, energy management systems, combined heat and power) and air conditioning to refrigeration and industrial processes.

In sum, the main benefits of improvements in energy efficiency are that they make modern energy services more affordable and accessible by reducing the energy required for any particular purpose and thereby reducing costs. It is only in the high-income economies that there is some suggestion that per capita energy use might eventually decline as incomes grow and energy needs become satiated. In developing countries, however, demand is set to grow substantially, even allowing for - and to some extent because of - improvements in energy efficiency, in any scenario of economic success.[13]

Reconciling increased energy consumption and environmental protection

Two important issues that arise in any discussion about meeting growing energy demand are: What will be the environmental impact, and can the impact be ameliorated at an affordable cost for developing countries? To answer these questions we need to distinguish between local and regional pollution on the one hand and global pollution from greenhouse gases on the other. For local and regional pollution the technologies are well developed, based on 40 years of operational experience in industrialised countries. For global warming the required technologies, while promising, are at a much earlier phase of development and use and raise different issues for policy.

Reducing local and regional pollution

Studies have estimated high social costs of pollution from energy production and use in developing countries (Lvovsky and Hughes, 1999; Lovei, 1995; Downing, Ramankutty, and Shah, 1997). The costs of pollution in cities are especially high:

- **Marginal damage costs per ton of local pollutants vary greatly across sources and locations and are much higher for small (low-stack) sources because of the dispersion pattern.**

- **For some fuel uses the marginal damage costs are as high as producer and retail prices - or even higher.**

- **Diesel-powered vehicles and small stoves or boilers burning coal, wood, or oil impose the highest social costs per ton of fuel.**

- **Sulphur deposition levels are already at 5-10 grams per square meter per year in the industrial areas of Indonesia, Malaysia, the Philippines, and Thailand, and at more than 18 grams in China. By comparison, deposition levels in the most heavily polluted parts of the industrialised world - the black triangle of Central and Eastern Europe - are about 15 grams.**

- **Local health effects dominate the damage costs. Lead blood levels during the early 1990s were 25 micrograms per decilitre in Mexico City and Budapest, 30 in Cairo, and 40 in Bangkok, well above the 2 micrograms per decilitre in the United States (reflecting an eightfold decline over the preceding 15 years).**

TABLE 11.6. RELATIVE POLLUTION INTENSITIES AND COSTS OF SELECTED LOW-POLLUTING TECHNOLOGIES FOR ENERGY PRODUCTION AND USE (INDEX = 100 FOR ALL HIGH-POLLUTING TECHNOLOGIES)

Source and pollutant	Low-polluting technology	Costs as share of supply or user costs (percent)[a]	Nature of low-polluting alternatives
Electricity generation (coal)			Natural gas; electrostatic precipitators, bag-house filters, flue gas desuphurization, integrated coal gasification combined-cycle technologies, and fluidised bed combustion (for coal); low nitrogen oxides combustion and catalytic methods.
Particulate matter	<0.1[b]	<0 - ≈2[b]	
Sulphur dioxide	0 - 0.5	5	
Nitrogen oxides	5-10	5	
Motor vehicles			Unleaded/reformulated fuels; catalytic converters. Improved fuel injection, engine design, maintenance. And 'proper' fuel use; catalytic converters.
Gasoline engines			
Lead	0		
Carbon monoxide	5	≈4 - 5 share of lifetime cost of vehicle fuel and equipment costs,	

		for gasoline and diesel engines	
Nitrogen oxides	20		
Volatile organic compounds	5		
Diesel engines			
Particulate matter	≈10 - 20		
Nitrogen oxides	≈40		
Traditional household fuels (wood and dung) in low income countries			Gas, kerosene.
Smoke (particulate matter, carbon monoxide, and sulphur)	<0.01	<0[d]	
Carbon dioxide emissions from combustion of fossil fuels			Advanced solar energy, wind, and other renewable energy technologies for power generation; biomass for liquid fuels and power generation; hydrogen from renewable energy sources and fuel cells for power

			generation and vehicles.
Electricity (developing countries)	0		
Electricity (developed countries)	0	≈0 - ≈20[e]	
Liquid fuel substitutes	0	≈30 - 50	

Note: Except for carbon dioxide all the estimates are based on technologies and practices commonly in use. a. Net private marginal costs are used because some technologies and fuels have benefits that go beyond their environmental benefits - use of gas as a domestic and industrial fuel is an example. Such investments are routinely justified in terms of their economic convenience or productivity relative to the alternatives, without reference to their environmental benefits, however important. b. Negative costs arise if gas is available for power generation as a substitute for coal. c. High emissions (especially of particulate matter) in developing countries stem very much from ageing vehicles, poor maintenance, and improper use of fuels (for example, kerosene instead of diesel). d. In urban areas and where traditional fuels are scarce, modern fuels are generally cheaper to use once the costs of household labour are taken into account, in part because of their higher energy efficiency (see chapter 10) and their convenience and savings in time (see discussion in text). e. Estimates are much lower for developing countries than for the northern industrialised countries because solar insolation is two to three times greater in developing regions and its seasonal fluctuation is one-third less.

Estimates are of long-term costs.

Source: ADB, 1991, and Charpentier and Tavoulareas, 1995 for electricity; Faiz, Weaver, and Walsh, 1996, for motor vehicles; Smith, 1993, for traditional fuels. Anderson and Chua, 1999, review the engineering economic literature, and Kiely, 1997, provides an introductory text on technologies; both have ample bibliographies.

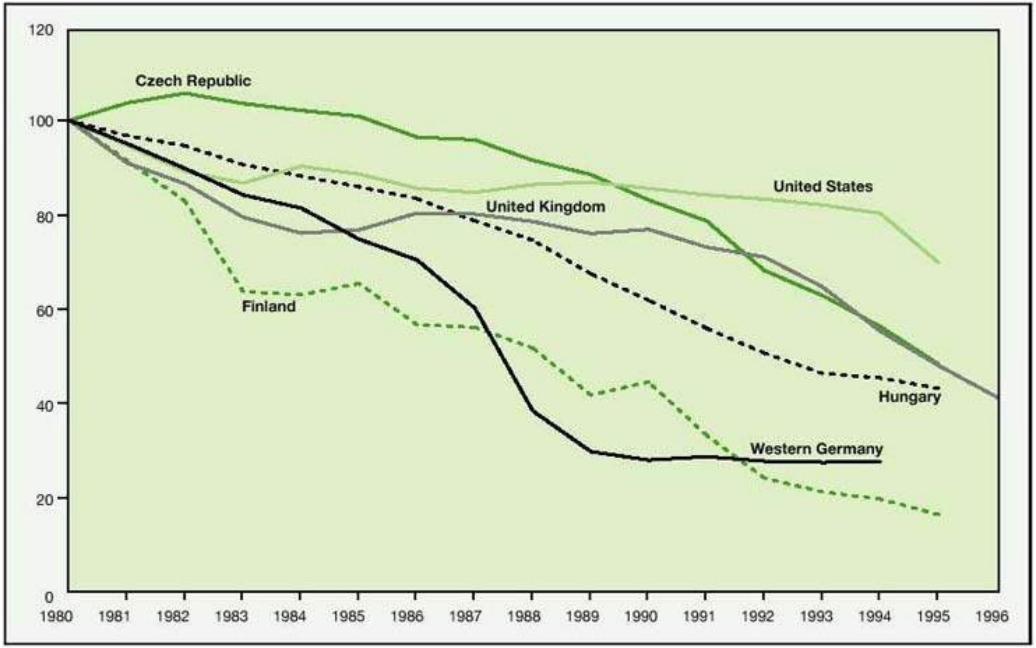


FIGURE 11.3. TRENDS IN SULPHUR DIOXIDE EMISSIONS, SELECTED COUNTRIES,

1980-96

Source: Data from OECD, 1997; U.S. EPA, 1997; and U.K. Department of Environment, Transport, and the Regions National Air Quality Archive (http://www.aeat.couk/netcen/airqual/).

There are several options for substantially reducing local and regional pollution loads over the long term. This is evident both from the experience of industrialised countries (table 11.6) and from comparisons of pollution loads in industrialised and developing countries (figure 11.3). Given the time required to incorporate low-polluting options in new investments and to replace the old capital stock, however, pollution is likely to rise before it falls. But the experiences of industrialised countries also shows that there is little doubt that major reductions of local and regional pollution from energy use could be achieved in the long term with supportive policies.

Low-polluting technologies, in wide use in industrialised countries, have led to appreciable reductions in smog, acid deposition, and emissions of lead, particulate matter, and volatile organic compounds; and although energy consumption per capita is an order of magnitude *higher* than in developing countries, local and regional pollution is an order of magnitude or more *lower* or (in the case of acid deposition) headed in that direction. (See chapter 3 for a full discussion of pollution loads in the industrialised and developing countries.)

The costs of controlling local and regional pollution are small relative to the total costs of energy supply or use. If coal is used as the principal fuel in electricity generation, the costs of pollution abatement range from 2 percent of supply costs for particulate matter (the most environmentally damaging of pollutants) to 5-10 percent for acid deposition. If gas is used as the principal fuel, the costs of pollution

abatement are negative once allowance is made for the higher thermal efficiencies and lower capital costs of the power plant. For motor vehicle emissions the absolute cost of abatement, including the cost of catalytic converters, is estimated at less than $0.04-0.15 per gallon of fuel consumed. Similarly, supplying modern fuels to households in place of traditional fuels significantly reduces both indoor and local pollution (see chapter 3) and, except in remote communities, the costs of energy supplies as well.

Simulations of the effects of introducing abatement policies for reducing acid deposition in Asia illustrate the potential of innovation for enabling developing countries to address environmental problems at an earlier phase of their development than did industrialised countries (Anderson and Cavendish, 1999; figure 11.4). Studies that assume that environmental problems will not be addressed until the per capita incomes of the main emitters in the region (China and India) approach those of industrialised countries when they began to address acid deposition in the 1970s (about $10,000[14]) put that date at half a century from now for China and nearly a century from now for India, even under optimistic growth rate assumptions. When the simulations are run under the assumption that countries in Asia take advantage of new methods of sulphur dioxide abatement that have emerged in recent years, including coal desulphurization and the use of gas for power generation (now a rapidly growing possibility in East Asia), the results clearly show the opportunity for solving the problem much earlier with greatly reduced pollution loads. Downing, Ramankutty, and Shah (1997), in a study of acid deposition in Asia, come to similar conclusions; so do the scenarios in chapter 9.

The relatively low costs of pollution control suggest that the required financing can be generated through policies that allow prices to reflect the marginal costs of supply,

including the costs of pollution control - the central goal of internalising externalities in market prices. Simulation studies consistently show that the extra investing, but would over time be offset by efficiency gains in the industry as a result of new thermal efficiencies in power plants, improvements in plant availabilities, reductions in distribution losses, and gains in managerial efficiency from liberalisation and improved forms of regulation (Cavendish and Anderson, 1994; World Bank, 1992). Thus while subsidies should not be necessaryto finance investments in reducing local or regional pollution, environmental regulation and taxation would be.

For some fuel uses the marginal damage costs are as high as producer and retail prices - or even higher.

In addition, experience in industrialised countries has shown that there are good economic returns to such investments through improvements in people's health and reduced damage to natural resources (chapter 3). In a review of U.S. experience, Davies and Mazurek (1998, p. 148) conclude that:

> **The macroeconomic effects of pollution control and regulation are generally modest. Regulation has had some adverse effects on GDP growth, but most economists think that the effect has been relatively small, and the negative effect fails to take into account most of the benefits of regulation.... When looked at as a whole, U.S. environmental progress has made economic sense. It can be shown that benefits exceed costs in a great number of cases.**

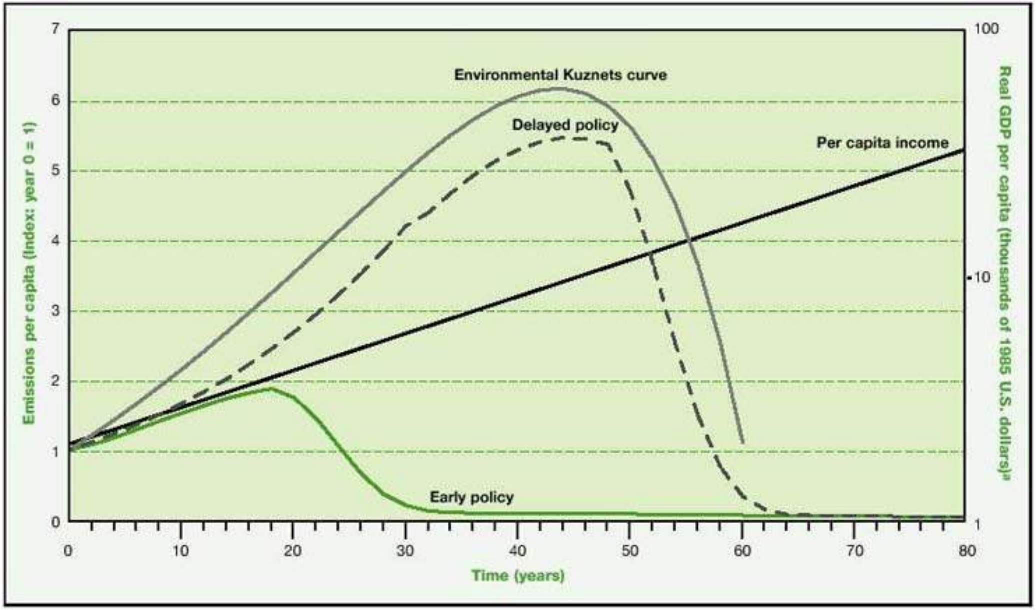


FIGURE 11.4. SIMULATED EFFECTS ON SULPHUR DIOXIDE EMISSIONS IN ASIA OF EARLY AND LATE ENVIRONMENTAL POLICIES

a. Adjusted for real comparative purchasing power using Penn World Table, mark 4 (Summers and Heston, 1991).

Source: Anderson and Cavendish, 1999; Selden and Song, 1994, for the environmental Kuznets curve.

In developing countries the net effects on growth should be even greater, since their

environmental priorities in the energy sector include the elimination of smoke, emissions of particulate matter, lead in fuels, and the indoor air pollution and damage to soils and forests arising from the use of traditional fuels. Thus there is no reason from an economic perspective why developing countries cannot adopt ambitious policies for reducing local and regional pollution from energy production and use. The technologies and practices are now available that should, if the 'right' policies are put in place, enable developing countries to reduce such sources of environmental damage at a much earlier phase of development than was the case for industrialised countries.

Mitigating global warming

The other energy-related environmental concern is global warming. For understandable reasons developing countries have been reluctant to commit themselves to emission reduction targets for greenhouse gasses. The costs of mitigation are thought to be too high, and there is some resistance to the notion that developing countries should not use fossil fuels to further economic development, as the industrialised countries did in the 19th and 20th centuries.

Yet developing countries may stand to benefit unexpectedly over the long term from international policies on climate change, particularly from the use of the renewable energy technologies now emerging from the energy research, development, and demonstration (RD&D) programmes of the industrial countries. In fact, some countries, such as Brazil, China, and India, have themselves begun to put resources into the development of renewable energy. The development and use of renewable energy have also become a focal point of the Global Environment Facility, the financing arm of the United Nations Framework Conventions on Climate Change and Biodiversity. What makes the technologies promising is the abundance of renewable energy resources and the falling costs being brought about by technical progress. (For

more detailed information about renewable potentials and technologies, see chapters 5 and 7.)

Abundant renewable energy resources. The Earth receives a yearly energy input from the sun equal to more than 10,000 times the world's consumption of commercial energy. Solar insolation varies from 2,000 kilowatt hours per square metre to more than 2,500 a year over vast areas of developing countries, from 800 to 1,700 in Europe, and from 1100 to over 2,500 in the United States. Photovoltaic systems and solar-thermal power stations are capable of converting 10-15 percent - 15-30 percent with further development - of the incident solar energy into electricity.

TABLE 11.7. USE AND COMPARABLE COST OF SELECTED RENEWABLE ENERGY TECHNOLOGIES, 1998

Technology	Average cost (U.S. cents per kilowatt hour unless otherwise indicated)	Comments
Wind (electric power)	5 - 13	Costs declined fivefold from 1985 to 1995.
Biomass		
Electric power	5 - 15	Steam cycle of 25 megawatts Brazil data. Declined by factor of three since 1980s.
Ethanol	$2 - 3/gallon	

Ethanol	$2 - 3/gallon ($15 - 25 gigajoule)	
Photovoltaic systems		Based on costs of $5 - 10/peak watt. Costs have declined 50-fold since 1975, 5-fold since 1980, 2-fold since 1990. Medium- and long-term storage a major issue. With battery storage, cost of $8 - 40/peak watt in off-grid, stand-alone applications are commonly reported; see chapter 7.
Insolation, 2500 kilowatt hours/square metre	20 - 40	
Insolation, 1500 kilowatt hours/square metre	35 - 70	
Insolation, 1000 kilowatt hours/square metre	50 - 100	
Thermal solar (electric	10 - 18	Parabolic troughs. Latest vintages, around 1990, in high insolation areas only.)

power)		
Geothermal	3 - 10	Costs vary greatly with location.
Gas-fired, combined-cycle power plant	3 - 5	Higher figure is for liquefied natural gas.
Grid supplies		
Off-peak	2 - 3	Depends on spikiness of peak
Peak	15 - 25	
Average, urban areas	8 - 10	
Average, rural areas	15 to >70	Rural areas in developing countries

Note: All figures are rounded. Estimates are adjusted to 10 percent discount rates.

Source: Based on the author's interpretations of the following reviews, of more than 500 papers and studies: Mock, Tester, and Wright, 1997, on geothermal; Larson, 1993, on biomass; Ahmed, 1994, on solar and biomass; Gregory, 1998, on several technologies, including fossil fuels; World Bank, 1996, on renewable energy and grid supplies in rural areas; and chapter 7 of this report. Refer to those sources for details and qualifications.

In theory, all of the world's primary energy requirements of 8 gigatons of oil

equivalent a year could be met on an area of land equal to about 0.25 percent of the land now under crops and permanent pasture.[15] There is thus no significant land constraint on the use of solar energy. The main issue is cost. Other renewable energy technologies, such as biomass and wind power for electricity generation, have greater land intensities than solar energy; they have already attracted significant investment.[16]

Encouraging technical progress and falling costs. The relative costs of fossil fuels and renewable energy can be assessed only within broad limits, even assuming reasonable stability of fossil fuel prices (table 11.7). The estimates shown indicate why niche markets have emerged for renewable energy in favourable locations: geothermal, wind, biomass for power generation; solar thermal in areas of high insolation; and photovoltaic systems for off-grid markets and for distributed generation when there is a good co-incidence of solar peak and demand peak. Renewable energy installations (excluding hydropower) generate about 30,000 megawatts world-wide. While small relative to the world's generating capacity (more than 3 million megawatts), this experience has provided good information on the costs and reliability of renewable energy technologies.

Two factors, often neglected, are also important to cost calculations. One is the comparative advantage developing countries may have in using renewable energy. Solar insolation, for example, is two to three times greater than in the northern regions of industrialised countries, and seasonal swings are much lower. For this reason developing countries may enjoy a five-to-one cost advantage in using direct solar technologies. The second factor concerns differences between average and marginal costs. In off-peak times the marginal cost of grid supplies may be one-quarter to one-third the average cost, while in peak times marginal costs can be as

much as two to five times higher than average costs - or even more. This differential has been obscured in many countries by the common practice of average cost pricing and, too often, by subsidies. But when there is a good co-incidence between solar peaks and demand peaks, there is an economic case for using photovoltaic systems for distributed generation. Better efficiency in the level and structure of prices will also be needed to provide proper incentives for solving the problem of intermittence in renewable energy supplies. Differential pricing, with high peak and low off-peak rates, provides the ideal incentive. Such pricing structures have already emerged at the bulk supply level in some countries with liberalised electricity markets (the United Kingdom is a prominent example).

Energy research, development, and demonstration. But we need to go beyond the (undoubtedly important) principle of 'getting prices right' for commercial investment and to revisit the case for technology development policies. Most member countries of the International Energy Agency have such policies in one form or another, aimed at developing new alternatives to fossil fuels. International economic co-operation to foster trade, investment, and the diffusion of know-how in these technologies has also begun to emerge, albeit on a small scale considering the task in hand (see section on liberalisation and globalisation).

Developing countries may enjoy a five-to-one cost advantage in using direct solar technologies.

The principal example of international co-operation is the Global Environment Facility.

The marketable permit systems and other flexibility mechanisms of the Joint Implementation and Clean Development Mechanism, if implemented, will be important extensions of these initiatives. But while public support for commercialisation and international co-operation has been growing, energy RD&D programmes in OECD countries have declined precipitously in the past 20 years. Many question whether they have declined too far, considering the severity of environmental problems and the competition from fossil fuels (see box 11.1 for a discussion of energy research and development).

Cost uncertainties and scenarios of carbon emissions. Notwithstanding the promise of renewable energy, the uncertainties remain appreciable. The future use of renewable energy will depend on its costs relative to the costs of fossil fuels and on taxes and regulation of carbon emissions. Minor changes in assumptions about the effects of innovation on costs, when extrapolated over long periods, lead to large differences in estimates of the energy supply mix, as do differences in assumptions about climate change policies.

It is possible (and many people hold this view) that renewable energy will remain confined to niche markets in the absence of climate change policies. It is also possible (and many others hold this view) that with further innovations and scale economies in manufacturing and marketing, renewable energy will eventually meet a substantial share of the world's energy needs.

Uncertainties about the costs of non - fossil fuel technologies and different assumptions about climate change policies are the main reasons why scenarios of carbon emissions differ so greatly. Industry scenarios (for example, Kassler's 1994 report for the Royal Dutch Shell group of companies) and the recent lower emission scenarios of the International Panel on Climate Change (Nakicenovic, Victor, and

Morita, 1998) show carbon emissions rising from 6 gigatons of carbon a year today to a peak of 10 gigatons by the middle of the century and then declining to low levels by the end of the century. These scenarios also allow for the emergence of other non - fossil fuel technologies and for technological surprise.

These results can be reproduced using elementary simulation models. The results of one such simulation for a developing country are shown in figure 11.5. They contrast the emissions associated with the country's early introduction of climate change policies with those that would arise if the country were to wait until its per capita income began to approach that of industrialised countries today, a projected delay of roughly half a century. Note the long lags before the full effects of the policies are felt, a (further) delay that arises from the scale of the problem of replacing fossil fuels in the energy supply mix and the longevity of investments in energy supplies from fossil fuels.

There is a wide range in costs for the early policy scenario. Significant investment would be required in the early decades, as is clear from the data in table 11.7 and from the report of the President's Committee of Advisers on Science and Technology noted in box 11.1. However, the costs in the long term may well prove to be small or negative. When the full probability distributions for the parameters representing the effects of technical progress on costs are included in the analysis, it can be shown that there is a significant chance of a technological and an economic surprise arising, so that alternatives might become less expensive than fossil fuels for a large number of applications. This outcome is consistent with the findings of the industry scenarios (Kassler, 1994). We cannot say with certainty that such a favourable outcome will materialise, and it may well be that a transition to renewable energy will eventually require a permanent and significant tax or regulation on the use of fossil fuels. But reflecting on the technological developments and reductions in the costs of energy

over the past century, who could say with confidence that the scope for innovation in alternatives to fossil fuels is exhausted or that addressing climate change is unlikely to yield a technological or an economic surprise?

BOX 11.1. HAS PUBLIC SUPPORT FOR ENERGY RESEARCH AND DEVELOPMENT DECLINED TOO FAR?

Public support for energy research, development, and demonstration (RD&D) programmes in OECD countries has declined considerably since 1985: by 80 percent in Germany, 75 percent in Italy, 50 percent in Canada, and 10 percent in Japan (where, as in France, nuclear power occupies the bulk of the budget) and the United States (IEA 1997a). Recent public energy RD&D expenditures in International Energy Agency (IEA) countries are about $8.5 billion a year. About 55 percent of spending goes for nuclear power and 40 percent for renewable energy and conservation.

In most countries the cuts were made across the board and equally applied. The cuts were motivated in part by market liberalisation, whose aim was to shift the onus for innovation to the private sector, and in part by competing demands on public revenues for social sector programmes. The decline in public support for RD&D also reflects discouragement with state-selected programmes supported by direct state expenditures in the period from around 1950 to 1990.

Following a major re-assessment of the approach over the past 15 years, public policies in several OECD economies are now moving towards a complex mix of incentives based on:

- Regulatory requirements for private industry to develop technologies with low carbon emissions.

- Technology-neutral tax incentives for the development of low carbon technologies.

- Marketable permit and related systems, such as the proposed programmes of Joint Implementation and the Clean Development Mechanism.

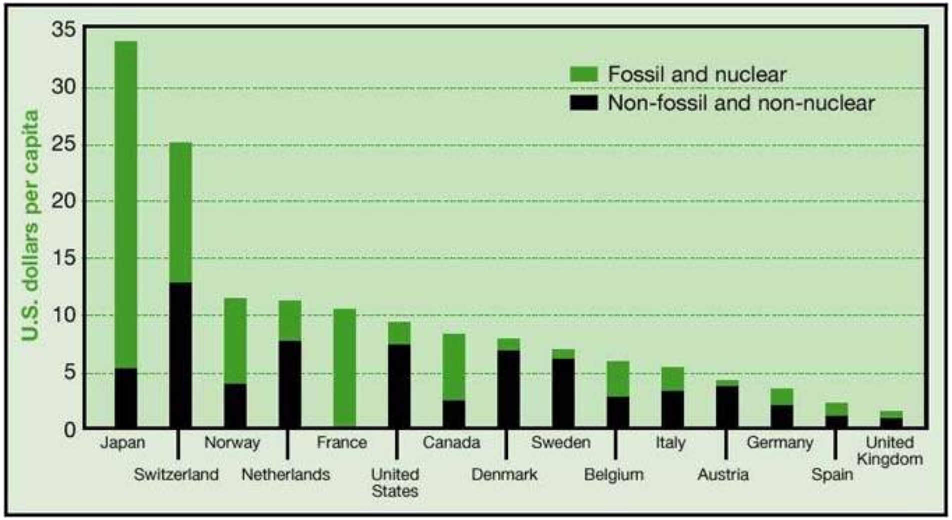
- Special financing facilities such as the Global Environment Facility that blend their own concessionary or grant finance with the hard finance of the multilateral development banks and industry to achieve a softer financial blend for innovative environmental projects.

These are all clearly more market-oriented initiatives that avoid the problems encountered previously under state-directed programmes. The main issue is whether the incentives provided today are sufficient in light of the emerging environmental problems and the continuing competition from fossil fuels.

The U.S. President's Committee of Advisers on Science and Technology (1999, p. ES-5) concluded that they are not. "[U.S. federal RD&D programmes] are not commensurate in scope and scale with the energy challenges and opportunities the twenty-first century will present....especially...in relation to the challenge of responding prudently and cost-effectively to the risk of global climatic change from society's greenhouse gas emissions". Yet on a per capita basis U.S. RD&D programmes on non-fossil and non-nuclear technologies are among the largest in the OECD (see figure).

What are the alternatives to providing incentives for RD&D? The costs of the non-fossil components of energy RD&D programmes are about $2.3 per ton of carbon emitted in IEA countries including nuclear power and less than $1 per ton excluding nuclear power. Economic estimates of the carbon taxes required to address the climate change problem are much larger, at five to several hundred dollars per ton.[1] When uncertainties are large, as they are in the case of developing technological alternatives in response to a highly uncertain problem such as global warming, it is a good policy, well supported by the principles of economic analysis, to invest in options that reduce uncertainties and costs.

1. "The World Bank Global Carbon Initiative", attachments to a published speech by James D. Wolfensohn to the UN General Assembly, June 25, (available from the World Bank Global Environment, Washington D.C.).



Public expenditure per capita on energy RD&D

Note: This figure understates the actual level of public RD&D in energy related matters since RD&D in some sectors - in transport and building sectors in particular - also has a large bearing on the development of energy-efficient technologies and practices.

Source: IEA 1997a.

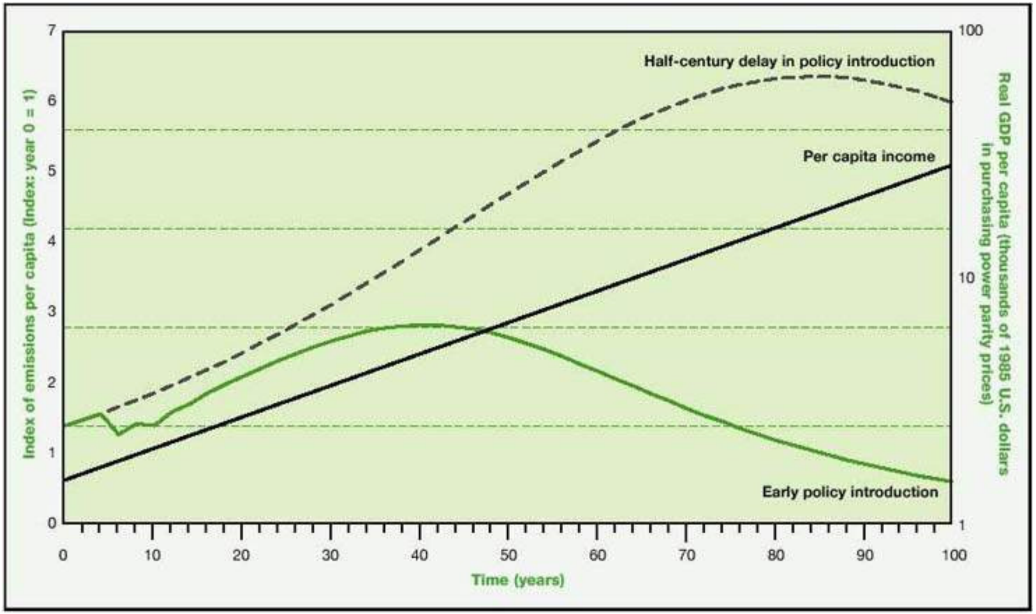


FIGURE 11.5. SIMULATED EFFECTS OF ENVIRONMENTAL POLICY ON CARBON DIOXIDE EMISSIONS FOR A DEVELOPING COUNTRY

Note: Initial GDP per capita is $1,500 and growth is 3 percent a year. The early fluctuations in emissions in the 'early policy' case arise from the initial price effects on demand.

Source: Special run by the author using the model described in Anderson and Cavendish, 1999.

Competition from fossil fuels and lessons from the history of nuclear power. In addition to the above-mentioned uncertainties, competition from fossil fuels continues to increase. Estimates of fossil fuel reserves are far greater today than they were 40 years ago, when nuclear power programmes were being initiated. Estimates for the 1955 UN Atoms for Peace Conference put proven reserves at 480 gigatons of oil equivalent and ultimately recoverable reserves at 2,300 (United Nations, 1955) - respectively one-quarter and one-twelfth of current estimates. With the convenience of hindsight, we now know that the underlying premise of the nuclear power programmes that were being advocated at the time - that fossil fuels would be severely depleted by the first half of the 21st century - was wrong, as were two other assumptions: that growing pressures on reserves would increase the costs of fossil fuels, while technical progress would lower those of nuclear power.

In fact, the opposite happened. Except during the oil price shocks of the 1970s, real oil prices have consistently been in the $10-20 per barrel range (in 1995 dollars) for 120 years, despite huge increases in demand. The prices of coal and natural gas (per unit of energy) have generally been even lower than those of oil (BP 1996).[17] Low costs were made possible not only by continued discoveries, but also by technological progress in exploration and production and throughout the downstream industries. In addition, continued technological progress in the electricity industry reduced both the capital and the fuel costs of generation from fossil fuels. In the 1950s the thermal efficiencies of new fossil fuel - fired stations were 30-35 percent; today they are around 45 percent for new coal-fired plant and 55 percent for gas-fired plant.

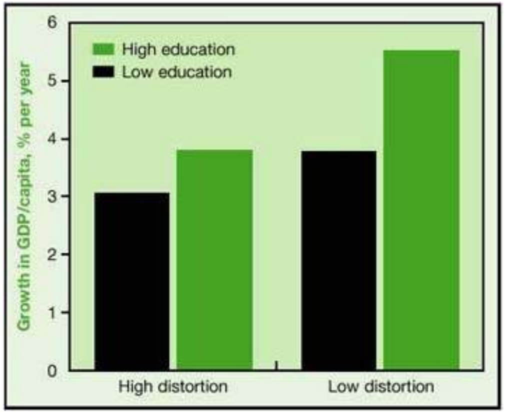
Technological progress and discoveries of reserves thus reduced the costs of power

generation from fossil fuels relative to nuclear power. The history of oil and gas is replete with predictions of rapidly depleting reserves and rising prices.[18] In addition, there are promising options for hydrogen production from natural gas and for coal bed methane in which carbon dioxide is re-injected in coal beds for enhanced methane recovery (on a closed, non-net-carbon-emitting cycle), used for enhanced oil recovery, or sequestered deep in saline aquifers (see chapter 8). In sum, non - fossil fuel technologies, including the emerging renewable energy technologies, will continue to face intense competition from fossil fuels for many years ahead.

Nevertheless, from an economic perspective the evidence allows for an optimistic conclusion: technologies are emerging that should enable the virtual elimination of carbon emissions from energy use should the need arise. This is so even if the higher energy demand scenario (scenario A) in chapter 9 were to materialise. The estimated incremental costs of abating carbon emissions are modest in relative terms: most studies put them at 1-6 percent of world economic product to achieve 50-60 percent abatement by the middle of the next century and 2-8 percent of world product by the end of the century.[19] Even at the higher end these estimates would amount to less than two year's growth of world product over a 50 year period and four year's growth over a century. They would shave less than 0.1 percentage point a year off the long-term growth rate (which averages about 2 percent a year in industrialised countries and more than 4 percent a year in developing countries with progressive economic policies).

BOX 11.2 HOW MARKET LIBERALISATION AND EDUCATION POLICIES INTERACT TO AFFECT GROWTH AND POVERTY REDUCTION

Studies of investments in education demonstrate the influence of a single policy variable on growth and poverty reduction in an environment of market liberalism. One study (World Bank, 1991) found that education investments have much larger impacts in countries that already enjoy a degree of economic liberalisation than in those that do not. The combination of liberal market policies and investments in education is particularly striking.



Box figure. Liberalisation, education investment, and growth of GDP in 60 developing economies, 1965-87

Note: High and low levels of distortion relate to the foreign exchange premium, a reasonable indicator of trade liberalisation. High distortion reflects a foreign exchange premium of more than 30 percent; low distortion, a premium of 30 percent or less. Education is measured by the average years of schooling, excluding post-secondary schooling, of the population ages 15-64. High education is defined here as more than 3.5 years; low education, as 3.5 years or less.

Source: World Bank, 1991.

The difference between the higher and lower growth cases is 2.5 percentage points a year. This estimate of what good policies might accomplish greatly understates the effect, as the authors acknowledge, because it concentrates on only two policy variables, is based on average figures for a large number of countries, and makes modest assumptions about what constitutes high education.[1] Yet even 2.5 percent a year, when compounded over a century, would mean a 10-fold increase in per capita incomes relative to the low-growth case - the difference between failure and success in development over the century.

1. World Bank (1997, fig. 5, p. 13) updated the estimates to allow for the quality of institutional development. This raised the estimate from 2.5 to 3 percentage points a year.

In sum? A scenario of low carbon emissions in the long term is technologically and economically achievable and is fully consistent with the goals of developing countries achieving economic prosperity (and enjoying higher levels of energy consumption) in the present century, and of the industrialised countries improving their prosperity.

Liberalisation and globalisation

In the past half century successive multilateral rounds of reductions in the barriers to trade and foreign investment have led to considerable increases in the level and globalisation of economic activity. Between 1971 and 1995, as world GDP expanded at almost 3 percent a year, international trade increased at 5.6 percent a year and now stands at more than 22 percent of world economic product. Foreign direct investment expanded even more rapidly, at 12 percent a year between 1980 and 1996, encouraged by liberalisation and privatisation of formerly state-owned companies. It accounted for more than 10 percent of total domestic investment in 1995.

What are the implications of globalisation for the energy industry? Market

liberalisation in the industry over the past two decades can be seen as a response to a range of problems and opportunities:

- **The growing difficulties of raising finance (especially in the electricity sector), a consequence of high levels of government intervention and subsidies.**

- **The growing difficulties of the public sector in providing for the financial losses of the state-owned industries.**

- **Deteriorating service levels in many countries, reflected in frequent black-outs and brown-outs.**

- **The need to reduce losses and cost inefficiencies.**

- **The increasing transparency of costs and investment decisions, in the electricity, nuclear power, and coal industries in particular, which led to increased questioning of the cost-efficiency of public investments in the industry.**

- **The rapid growth of energy markets in developing regions and related opportunities for trade and investment in all energy sectors - electricity, coal, gas, and oil.**

- **New opportunities for trade and investment in high-efficiency technologies, such as combined-cycle power plants, brought about by the growth of world gas reserves.**

But as the world economy has become more integrated, there are fears that the rapid growth of trade and investment will have two undesirable side effects. The first is that

the most impoverished people will be left out of the process of economic growth and development - only higher income groups will benefit - and inequality, poverty, and social conflict will intensify. The second is that there will be deleterious effects on the environment.

These fears are not unfounded. But they rest on the (perhaps less commonly articulated) assumption that complementary policies will not be put in place to achieve growth on a broad basis and to protect the environment. It is not possible to predict reliably whether such policies will be pursued, but we do know that the effects will be profound one way or the other. (See box 11.2 for a discussion of the influence of just one policy variable, investment in education, that has been shown to be crucial for improving growth and reducing poverty.)

If complementary policies are in place, the rate of economic growth and development on a broad basis will be appreciably higher under liberalisation. Environmental policies and a range of other policies - health and population, agricultural extension, vocational training, physical infrastructure, and social infrastructure, including a regulatory framework for industry and commerce[20] - are also complementary to the growth process. No policy of market liberalisation can succeed without them.

On the environmental front there has already been a substantial response by the energy industry. Trade and foreign investment - in environmental as in other technologies - are ideal conduits for technology transfer and a means of enabling developing countries to address their local and regional environmental problems at a much earlier phase of development than industrialised countries did. The new forms of regulation that are accompanying liberalisation of energy markets also provide an opportunity for incorporating investment incentives for the development and commercialisation of environmentally friendly technologies (renewable energy,

hydrogen and fuel cells).

The problem of access will be more of a challenge. Providing modern energy services to perhaps 6 billion new customers must be one of the primary goals of the energy industry in this century. But it is clear from the range of complementary policies that are needed for market liberalisation to work that the industry cannot accomplish this alone. All markets in open societies function within a framework of laws, legislation, standards, and public and private information services designed to improve the clarity, integrity, and equity of economic transactions. This framework is the 'ghost in the machine'. Without it the risks of investment rise for any industry attempting to address the problem of access by investing in low-income markets, and without it sustained income growth in these markets will also be more difficult to achieve.

While there is much evidence to show that liberalisation should facilitate service extension, progress will need to be monitored. There is a danger that the industry may concentrate on the easier, more established markets in urban areas where demand growth is high. Some financial or regulatory incentives may be required to address the problem. While the evidence is still ambiguous, it is noticeable in the electricity sector that private investment in liberalised markets has so far been concentrated either in greenfield investments in power generation or in the acquisition of assets, with relatively little investment in the expansion of distribution (table 11.8).

Technologies are emerging that should enable the virtual elimination of carbon emissions from energy use should the need arise.

While it is possible that these investments in assets are a prelude to service expansion and extension, service extension is too important to rest solely on unmonitored assumptions. There will thus be a need for independent oversight both of the industry and of the regulatory process. Ground rules for regulation (discussed in the concluding section) will not only need to concentrate on the usual goals of monopoly avoidance and economic efficiency, but also on the problems of widening public access to energy services.

Conclusion: economic perspectives on policy

Over the next half century the energy industry will need to reach another 6 billion people or more (depending on population growth), while meeting the rising demands of the 4 billion already served. It will need to do this while substantially reducing local and regional pollution levels, particularly in developing regions, where the task of pollution abatement has hardly begun, and while developing new technologies and practices for reducing global carbon emissions and other greenhouse gases in the long term.

Several lessons of experience and ground rules for policy can be derived from a large number of studies that have reviewed energy and environmental policies:

The extension of modern energy supplies to people currently without them cannot be accomplished by the industry acting in isolation, but will depend also on the quality of development policies. Income growth is the main determinant of people's ability to afford and use modern energy forms. If development policies fail to promote economic growth on a broad basis, attempts by the energy industry to widen access will have limited success. If development policies are progressive, the industry (and its regulators) can be confident that markets will emerge in low-income as well as higher

income communities to meet emerging demand and so will improve the social and economic situation of billions of people.

The liberalisation of energy markets, which experience has shown to be fundamental for the efficient growth of the industry, is also crucial for widening access. The liquefied petroleum gas (LPG) market in Brazil illustrates this point. By 1991 it served nearly 90 percent of the population. As a cooking fuel LPG is 10 times more energy efficient than wood fuel and several thousand times less polluting. In Brazil it is supplied entirely by private enterprise. The only times investment and progress towards the extension of LPG service suffered were when the government heavily regulated its price and distribution (Reis, 1991). The World Bank (1996) reports a similar experience in Hyderabad, India. As a consequence of liberalisation of the energy markets, LPG use expanded from the richest 10 percent of households in 1980 to more than 60 percent of households in the early 1990s, even as the population doubled.

TABLE 11.8. PRIVATE INVESTMENT IN DEVELOPING COUNTRY POWER SECTORS, 1994-98

Type of activity	Capacity financed (gigawatts)	Investment (billions of U.S. dollars)
Greenfield	36	46
Privatisation	26	14
Distribution	0	58
Total	62	117

Source: Martin, 1999, who comments that the greenfield investments are mainly in generation.

The goals of liberalisation extend to trade and foreign investment in energy technologies and services. Enabling trade and foreign investment in energy technologies and services will allow the energy industry to apply its considerable financial, technical, and managerial resources to improving and extending energy supplies. Trade and foreign investment are also ideal conduits for the transfer of efficient end-use and environmentally improved technologies.

Economic efficiency provides a good basis for regulation. It points to a range of indicators for assessing an industry's performance. It requires regulators to look at measures of cost and price efficiency, at environmental performance (since the persistence of undesirable external costs is a source of economic inefficiency), and at the industry's efforts to extend service. The following are some ground rules for the electricity industry; parallel ones can be developed for gas:

- ***Price efficiency.* Prices reflect the level and structure of the marginal costs of supply, differentiated by time of day, season, and voltage levels (an outcome of pool pricing and supply competition in liberalised markets). Marginal costs include the costs of compliance with environmental policy.**

- ***Subsidies.* These are avoided, with financially minor but socially important exceptions, and are not such as to undermine the financial performance of the industry. They are also unnecessary, since the industry has long been capable of financing its own expansion - including the expansion of service to new consumers - through retained earnings and recourse to capital markets. Exceptions may be 'lifeline' rates for household consumers with low levels of consumption, allowances for the higher fixed costs of the extension of service to new areas, and investments in RD&D projects.**

- ***Cost efficiency.*** **Typical yardsticks are the costs and efficiencies of thermal plant relative to known international best-practice standards, reserve plant margins, electrical losses, and plant availability factors.**

- ***Quality of service.*** **Probabilities of loss of load and brown-outs are good indicators of service quality.**

- ***Widening access.*** **The portion of the population served by grid or off-grid schemes is monitored and used as a measure of progress towards the goal of providing universal service.**

- ***Commercialisation policies for environmental innovation.*** **New forms of arm's length regulation following market liberalisation provide opportunities for establishing new forms of incentives for the development and commercialisation of environmentally friendly technologies. These include competitive bidding processes and incentives for private investment. The modularity of many of the emerging technologies means that the financial risks are small, especially relative to those of the nuclear power industry in the 1950s to the 1970s.**

Providing modern energy services to perhaps 6 billion new customers must be one of the primary goals of the energy industry in this century.

Taxing energy is not an effective instrument of environmental policy, not with- standing many claims to the contrary. The case for energy taxes has long been widely

accepted on the grounds that they are an efficient form of taxation - they raise revenues without, it is thought, seriously distorting economic activity. The case for imposing additional energy taxes on environmental grounds, however, is not well founded. Such taxes increase revenues while having negligible effects on pollution. If pollution is to be reduced, there is no substitute for taxing or regulating pollution directly.

There is no reason, from either a technological or an economic standpoint, why the world cannot enjoy the benefits of both high levels of energy use and a better environment. Technological and managerial options are already available or capable of being developed that would substantially solve both local and global environmental problems from energy use at costs that may be large in absolute terms but are small relative to the long-run costs of energy supplies. Reducing local pollution is likely to raise rather than diminish economic output because of the attendant reduction in external costs. This conclusion should be especially heartening to developing countries, whose energy consumption will rise substantially as they strive to achieve economic prosperity.

In light of the promise of new, 'environmentally friendly' energy technologies on the one hand, and of emerging environmental problems on the other, there is a good case for revisiting the role of technology policies, including public support for RD&D. There is ample evidence of market-led technical progress in the energy industry: reductions in the costs of off-shore oil and gas exploration, improvements in the thermal efficiencies of power plant and reductions in the costs of electricity supply, reductions in power plant lead-times, and the ability to develop technologies for reducing pollution by orders of magnitude, to note a few.

Yet many people have argued, in response to concerns about climate change - and

governments in the OECD countries are, by and large, accepting the arguments - for public or regulatory support for the industry to develop new non - fossil fuel technologies, based on renewable energy and fuel cells and hydrogen. Such policies, which differ in detail and scale but not in intent between countries, hold the potential for economic and technological surprise. These areas are fertile ground for industry RD&D - areas that the industry might otherwise have ignored because of the abundance of fossil fuel reserves.

In view of the climate change problem, energy technology development and commercialisation programmes for climate friendly technologies also need to become more outward looking and international in scope. Developing countries especially need to become engaged in the development and use of such technologies. Aside from bilateral initiatives there are three complementary instruments of policy well suited to this purpose: the Global Environment Facility, the financing arm of the Framework Conventions on Climate Change and Biodiversity; Joint Implementation and the Clean Development Mechanism, which, if ratified, will enable companies to reduce carbon emissions through foreign investment when (as it often will be) it is cheaper to do so abroad than in the home country; and regulatory and tax policies to provide financial incentives for the early development and use of non - fossil fuel options in developing countries. There are now many examples in the OECD countries to show that such policies can be pursued in market-oriented ways without compromising the financial integrity of the industry.

Financial analysis consistently shows that, under enlightened regulation, the energy industry is capable of mobilising the financial resources required to expand services and address environmental problems through a mix of internal cash generation and recourse to the financial markets. As the report of the World Energy Council (WEC 1997, p. iv) concludes: "global capital resources in principle are more than adequate

to meet any potential demands coming from the energy sector. These demands are unlikely to exceed 3-4 percent of global output, the same proportion that has prevailed over past decades", a period of rapid industry expansion similar to that of the trajectory in the high-growth scenario (Scenario A) in chapter 9. The same conclusion applies to the provision of finance to meet the cost of solving local and regional environmental problems. These costs are unlikely to exceed more than 5-10 percent of the costs of supply, and any increase in costs is likely to be more than offset by gains in efficiency. Pollution should be greatly abated and the costs of energy supplies should fall. The financial requirements of the RD&D effort required to develop new non - fossil fuel technologies are also likely to be relatively small.

The main financial problem ahead could be posed by the capital requirements of developing countries. But if this materialised, it would be a self-inflicted problem. As the World Energy Council (WEC 1997, p. iv) further argues, "Contrary to popular belief, savings rates in many developing countries are double those of the US and generally one third greater than those of Europe or Japan". A large proportion of the required finance could be generated internally, with the remainder coming from international capital markets, which should in a favourable economic environment find investments in energy among the most attractive of options. The key is to offer a system of arm's length regulatory policies that allow investors to enter energy markets and to earn good rates of return while enabling the industry to extend service and reduce pollution.

Notwithstanding an immense literature on the subject of energy and the environment, four propositions remain needlessly controversial and a source of much confusion, not least among the policy-making community. They are that:

- **Local, regional, and global pollution arising from energy production and use**

can be virtually eliminated through technological substitution towards low-polluting forms of energy. With the important but partial exception of carbon dioxide abatement, where significant RD&D and commercialisation efforts for new technologies are merited, alternative fuels and technologies are already available or emerging.

- **Thanks to developments in pollution prevention and control, most stemming from recent policies in industrialised countries, developing countries can aspire to eliminate major forms of pollution at a far earlier phase of development - in most cases in the first third of this century - than the industrialised countries before them.**

- **The costs would not be large in relative terms and could be financed internally through the application of standard instruments of environmental policy.**

- **A low pollution future is fully consistent with higher levels of energy use in developing countries and the achievement of economic prosperity on a broad basis. A low pollution future is also consistent with high levels of energy use in industrialised countries, provided that efforts to develop the required technologies and practices continue.**

In workshops and though other forums we need to debate such propositions further, to show just what enlightened policies might accomplish.

Notes

1. See glossary for definition of terms.

2. This figure, reported in World Bank (1996), was compiled and presented initially by Zihong Ziang in an unpublished research note for the World Bank. Ziang surveyed energy statistics from a large number of reports in the World Bank's files. Figure 3.1 in chapter 3 provides a regional breakdown of the estimate of unserved populations.

3. See Lebergott (1993, table II.16, p 107), World Bank (1996, p 39-40), and Pearson (1994).

4. Explaining this statistic, Lebergott footnotes: "As of 1990, a yearly estimate of 4,420 cloth diapers per child, plus 8,060 gallons of water to rinse and wash them and 2.5 years in diapers" appears in a survey by Arthur D. Little Inc.

5. The estimates from a survey by Whittington, and others. (1994) on water vending in Ukunda, Kenya. are based on an unpublished survey undertaken by water supply engineers in Lagos in 1986 in connection with a World Bank project; the average distance over which the water was carried was a quarter of a mile.

6. Recent surveys of rural families in countries as diverse as Colombia, Jordan, Nepal, and Ukraine on their preferences for cooking fuels yielded identical results: the preferred fuel was gas or LPG, followed by kerosene and then wood. But the actual choice depended crucially on availability and costs (with costs varying immensely with the accessibility of the village and the quality of roads). Where wood was locally abundant, low- (but not high-) income families would use it until local resources were depleted. I thank the following students for undertaking surveys on preferences of rural people: Mike Hugh (in Jordan), Paras Gravouniotis (Nepal), Ernesto Salas (Colombia) and Nick Fraser (Ukraine) on field trips to these countries. The results are available in UNDP files.

7. Forecasts are reviewed in IPCC (1995 a, b) and Nakicenovic, Victor, and Morita (1998), which summarise more than 300 projections of world energy demand and carbon emissions.

8. I thank Eberhard Jochem for this figure and comments on it.

9. See Schipper and Meyers (1992); U.S. Congress (1995 a, b); Watson, Zinyowera, and Moss (1996); WEC (1993); and IPCC (1995); chapter 6 provides further evidence and an ample bibliography.

10. As discussed below, the annual rate of improvement in energy efficiency is thought to be in the range of 0.5 to 1.5 percent a year. If the latter figure holds, or even a figure of 1 percent a year, then an economy whose per capita income elasticity has declined to the 0.25. to 0.5 range and whose long-term growth rate is 2-3 percent a year could easily enter a period in which the long-term trend in energy demand is negative.

11. The actual effect on demand depends on two factors: the effects on costs and prices, and the price elasticities. The change in demand (D) following a change in price (P) is given by DD/D = aDP/P, where a is the price elasticity. Suppose energy efficiency reduces energy needs for a given application by a factor of 2, but also reduces the costs by the same amount; if the price elasticity is - 0.5, demand will fall by only 0.5 × 0.5, or 25 percent, not by half as predicted by engineering calculations, which neglect the point that the number of applications commonly rise following a reduction of price. Overall, since energy demand is fairly price inelastic, the prevailing consensus is that energy efficiency will lower energy demands relative to prevailing trends. However, the effect is smaller than often thought, and much depends on the price elasticity for the particular application. Also important, of course, are the prices

of the appliances.

12. In this respect it is lamentable that a commonly used index of environmental damage is energy consumption, when as argued earlier energy is a good not a bad, and the essential task for environmental policy is to abate the pollution from energy use not energy use itself.

13. For values of γ = 1.0, *g* = 4, *n* = 2, *x* = 1.5 (the higher limit), for example, and neglecting for now any declines in the costs and prices of energy brought about by further improvements in energy efficiency, the long-term growth rate would still be more than 4 percent a year in developing regions, with demands doubling every 15 to 18 years.

14. In 1985 prices. In these studies of the environmental Kuznets curves, per capita incomes are based on real comparative purchasing power data provided from the Penn World Tables (mark 4; Summers and Heston, 1991). Such data point to significantly higher real incomes in developing countries than are provided in national income data converted at official exchange rates. The environmental Kuznets curve (the inverted U-shaped hypothesis) is controversial and was never put forward by the late Simon Kuznets himself. As a device for predicting future trends in pollution, it has been discredited.

15. In practice, rooftops and desert areas would be used for the direct solar technologies, such that there would be little or no competition for arable lands arising from these technologies.

16. Visual intrusion is often a serious problem with wind and is now leading several European countries to move to introduce 'offshore' wind farms.

17. The prices per British thermal unit (Btu) were $3.20 for oil, $1.50-2.50 for gas, and $1.50 for coal in 1995, with the price of gas varying with region. The figure for coal is based on a conversion factor of 27 million Btu per tonne.

18. See Odell (1998), who draws attention to past errors of under-estimating the capacity of the fossil fuel industry to discover new reserves and lower costs, and the moral to be drawn from this.

19. See Weyant (1993) and Grubb, and others (1993). Estimates vary with assumptions about the rate of progress in the development of non-carbon technologies. As noted earlier, these estimates are conservative and fail to consider the possibilities of the innovation leading to technologies with costs lower than those of fossil fuels. So the ranges are actually from < 0.0 to the upper estimates cited here.

20. For an earlier assessment of the effects of social and economic policies on growth, see Harberger (1984). The World Bank's *World Development Reports* provide several syntheses of the effects of social and economic policies on the growth and distribution of per capita incomes and contain ample bibliographies.

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Chapter 12. Energy Policies for Sustainable Development

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ABSTRACT

The scenarios described in chapter 9 indicate that changes are needed if energy systems are to promote sustainable development. The key challenges are expanding access to affordable, reliable, and adequate energy supplies while addressing environmental impacts at all levels. Policies can support sustainable development by:

- **Delivering adequate and affordable energy supplies - including liquid and gaseous fuels for cooking and electricity for domestic and commercial use - to unserved areas.**
- **Encouraging energy efficiency.**
- **Accelerating the use of new renewables.**
- **Widening the diffusion and use of other advanced energy technologies.**

With the right policies, prices, and regulations, markets can achieve many of these objectives. But where markets do not operate or where they fail to protect important public benefits, targeted government policies, programmes, and regulations are justified when they can achieve policy goals.

The broad strategies to encourage sustainable energy systems are straightforward. But they require wider acknowledgement of the challenges we face and stronger commitment to specific policies. The strategies include:

- **Making markets work better by reducing price distortions, encouraging competition, and removing barriers to energy efficiency.**
- **Complementing energy sector restructuring with regulations that encourage sustainable energy.**
- **Mobilising additional investments in sustainable energy.**
- **Accelerating technological innovation at every stage of the energy innovation chain.**
- **Supporting technological leadership by transferring technology and building human and institutional capacity in developing countries.**
- **Encouraging greater international cooperation.**

The challenge of sustainable energy includes crucial enabling roles for governments, international organisations, multilateral financial institutions, and civil society - including local communities, business and industry, non-governmental organisations (NGOs), and consumers. Partnerships will be required, based on integrated and

cooperative approaches and drawing on practical experience. A common denominator across all sectors and regions is setting the necessary framework conditions and ensuring that public institutions work effectively and efficiently with the rest of society to achieve sustainable development.

Energy can be a powerful tool for sustainable development. But redirecting its power to work towards that goal will require major policy changes within the overall enabling framework. Unless those changes occur within the next few decades - and are begun without further delay - many of the opportunities now available will be lost or the costs of their eventual realisation (where possible) greatly increased. Either way, the ability of future generations to meet their needs would be gravely compromised.

At the core of any sustainable energy strategy is a vision for improving the provision and use of energy so that it contributes to sustainable development. For that to happen, policies must widen access to reliable and affordable modern energy supplies and reduce the negative health and environmental impacts related to energy use. Increased energy supplies and more efficient allocation of resources for sectoral investment will also be required to support economic development. The key requirement is that steps be taken to make markets work more effectively, or to help build energy markets where they do not exist.

A competitive market is the most efficient allocator of resources and is capable of providing high levels of consumer service and satisfaction. Thus a key element of a sustainable energy strategy should be to strive for, and to maintain, competitive market conditions. But the market alone cannot be expected to meet the needs of the most vulnerable groups, to protect the environment, to ensure energy security in the face of politically motivated disruption, and to support other public goods, such as

basic research that underpins the innovation and diffusion of new technologies. In general, however, given the proper framework set by government - with competitive pricing and effective regulation - markets can achieve many of the objectives of sustainable energy.

Where markets still fail to protect public benefits, targeted government interventions are indicated. The need should depend on whether government intervention will produce the desired results. Government interventions tend to be less efficient than market approaches and often have unintended consequences at odds with their original aims.

The market alone cannot be expected to meet the needs of the most vulnerable groups, to protect the environment, to ensure energy security, and to support other public goods.

Moreover, the introduction of sound policies does not prevent backsliding. For these reasons there is a need to adopt a pluralistic approach, to try different approaches, to learn from the experiences of other countries, and to be prepared to adjust policies in light of lessons learned domestically and internationally.

Chapter 9 shows, through energy scenarios, that our world needs to change direction if the goal of sustainable development is to be achieved. Change takes time. Economic, social, and political obstacles must be overcome. The life cycle of some investments is long, and change cannot always be readily accelerated. New, environmentally friendly technologies cannot be summoned out of thin air in the quantities and in the places

required. There is inertia in behaviour and consumption patterns. There is reluctance to pay now for uncertain, or even probable, future benefits. Widespread public awareness and support need to go hand in hand with sound political leadership and policy-making if successful change is to come about. Our world does not seem ready to change in the direction and to the extent required. But unless an early start is made on changing direction, the delay will almost certainly result in additional costs even where change is still possible - and various long-term development paths are likely to get blocked off (WEC, 1995; Nakicenovic, Grbler, and McDonald, 1998).

TABLE 12.1. DEFINING GOALS, STRATEGIES, POLICIES, AND POLICY INSTRUMENTS

Term	**Definition**	**Example**
Goal	Overarching aim or framework	Sustainable development
Strategies	Broad paths to reach a goal	Using energy provision and use to foster sustainable development
Policies	Courses of action to implement strategies	Making markets work more effectively by: • Restructuring the energy sector • Attracting private capital • Phasing out subsidies for conventional energy supply and consumption • Internalising externalities • Strengthening regulations • Supporting energy sector innovation • Accelerating the deployment of sustainable energy technologies • Promoting energy efficiency

		• Building institutional and human capacity in sustainable energy • Improving international cooperation and linkages between trade and the environment
Policy instruments	Specific measures used	• Efficiency standards • Public procurement policies • Voluntary agreements • Appliance labelling • Externality taxes and incentives (such as carbon taxes and early retirement incentives for older, less efficient, more polluting energy-using devices) • Fuel switching • Obligation to buy energy from renewable sources • Obligation to supply energy from renewable sources • Systems benefit charges (otherwise known as public benefits funds) • Supporting research and development demonstration projects • Lowering the cost of new technologies for more rapid deployment

BOX 12.1. THE NEED FOR A NEW ENERGY PARADIGM

Traditional paradigm	Emerging paradigm
Energy considered primarily as a sectoral issue	Greater consideration of social, economic, and environmental impacts of energy use
Limitations on fossil fuels	Limitations on the assimilative capacity of the earth and its atmosphere

Emphasis on expanding supplies of fossil fuels	Emphasis on developing a wider portfolio of energy resources, and on cleaner energy technologies
External social and environmental costs of energy use largely ignored	Finding ways to address the negative externalities associated with energy use
Economic growth accorded highest priority (even in prosperous economies)	Understanding of the links between economy and ecology, and of the cost-effectiveness of addressing environment impacts early on
Tendency to focus on local pollution	Recognition of the need to address environmental impacts of all kinds and at all scales (local to global)
Emphasis on increasing energy supply	Emphasis on expanding energy services, widening access, and increasing efficiency
Concern with ourselves and our present needs	Recognition of our common future and of the welfare of future generations

Policy goals and challenges

The policies considered here are targeted towards addressing the needs of people who do not have access to modern energy carriers, making energy supplies more reliable and encouraging the more efficient use of energy, and accelerating the development and wider deployment of new renewable technologies and clean and safe advanced fossil fuel technologies.[1] Clean, efficient, and safe technologies are either under-exploited or need to be developed. But such technologies have the potential to address the health and environmental problems associated with conventional fossil fuel technologies.

The broad policies to encourage sustainable energy systems are straightforward. But taken together and implemented effectively, they would represent a significant departure from current practices. They are largely aimed at harnessing market efficiencies to achieve sustainable development. They include, under the broad heading of making markets work better:

- **Energy sector restructuring, where this is not already taking place.**
- **Attracting private capital.**
- **Phasing out subsidies for conventional energy supply and consumption.**
- **Internalising externalities, such as health and environmental impacts.**
- **Promoting energy efficiency.**
- **Supporting energy sector innovation and the wider and accelerated use of sustainable energy technologies.**
- **Building institutional and human capacity in sustainable energy.**
- **Introducing wider-ranging and more effective regulatory measures, to improve market operations and their public benefits.**
- **Achieving more effective international cooperation, as well as closer links between multilateral trade and environmental measures.**

Table 12.1 provides the framework for the overarching policy goal of sustainable development, along with supporting strategies, policies, and instruments that would

help markets work better.

Changes are occurring around the world in all the above directions, but on neither a wide enough basis nor at a rapid enough pace given the scale and range of the challenges to sustainable development. Without an appropriate sense of urgency, it becomes difficult to muster the political will and public support to take the needed actions. This report is one attempt to convey how much is at stake - and how soon action is needed to initiate what will be a long process of change before sustainable energy development (in both the static and dynamic senses) can be securely acknowledged.

Even though there is not yet a widely shared sense of urgency about the need to shift to a sustainable energy path, many sustainable energy policy instruments enjoy widespread support. These include efforts to raise the efficiency and quality of energy services (heat for cooking and warmth, cooling, lighting, mobility and motive power) and to put in place social policies that address the plight of people who cannot afford energy services. Similarly, where local environmental conditions have deteriorated to an unacceptable level, communities often find alternative ways of doing things.

The greatest challenge comes when society is asked to move from addressing tangible current needs to taking actions to manage environmental resources for the future and for the sake of future generations. Taking such actions in the face of competing short-term interests will require a major reorientation in the approach to energy and energy services. What is required is a new global consensus, essentially the evolution of a new energy paradigm aligned with the goal of sustainable development (box 12.1). This, in turn, needs to be reflected in national, local, and individual perspectives and priorities.

For such a shift to occur, the sustainability debate will need to move to centre stage, accompanied by much higher public awareness, information, and commitment. If public support for sustainable energy development is not forthcoming, it will be extremely difficult to implement many of the policies discussed here.

The findings so far

Chapters 2-4 show that energy is far more than a sectoral issue - it cuts across many aspects of sustainable development and is vitally connected to economic prosperity, social well-being, environmental issues, and security. The expansion of choices that the wider availability and higher quality of energy services can make possible is a fundamental aspect of human development. But modern energy services are currently beyond the reach of about one-third of the world's people. And for development to be sustainable, the demand for affordable energy services must be met in ways that protect human health and the local, regional, and global environment, as well as provide reliable supplies.

Chapters 5-8 indicate that technical progress has helped identify ample energy resources - fossil fuel, renewable, and nuclear - to support future economic and social development. Thus the availability of energy resources is not likely to be a serious problem in the next century. The critical challenge is finding ways to use these resources at reasonable costs and in ways that do not damage the environment. The health and environmental implications of meeting the world's energy demands suggest that energy technologies with near-zero emissions will eventually be required to ensure sustainability. Technologies are already available to increase the use of renewable energy sources and improve energy end-use efficiencies. Emerging innovations offer the potential to use conventional sources of energy (fossil fuels being the most significant) in ways that are cleaner, more efficient, safer, flexible, and

affordable.

Chapters 9 and 10 demonstrate that the current mix of energy sources, energy infrastructure, and energy end-use applications is not efficient enough, diverse enough, or clean enough to deliver the energy services required during this century in a sustainable fashion. Incremental improvements are occurring - such as the rapid deployment of efficient combined cycle gas turbines for electricity generation, and wider use of renewables and other environmentally friendly technologies. But the scenarios described in chapter 9 show that a huge increase in the scale, pace, and effectiveness of policy initiatives and measures will be required to change course to a sustainable path. In the absence of such changes, sustainable energy development is unlikely to be achieved.

Defining the goals of policy

Chapter 1 provides a definition of sustainable development. The importance of the Brundtland Commission's definition was that it balanced the need to address current realities and priorities - of poverty, deprivation, and inequity - with the needs of future generations and the desirability of maintaining resources and biological diversity.[2] Chapter 9 also addresses the idea of sustainability, using a series of indicators.

The concept of sustainability was discussed further at the Earth Summit (officially known as the United Nations Conference on Environment and Development) held in Rio de Janeiro in 1992 and in one of the summit's main outputs, Agenda 21 (particularly in chapter 9; UN, 1992). The 1997 report of the UN Secretary-General on progress achieved since the Earth Summit states that the secretariats of the organisations of the UN system believe that sustainable development "should continue to provide an 'overarching' policy framework for the entire spectrum of UN activities

in the economic, social and environmental fields at the global, regional and national levels"(clause 139; see Osborn and Bigg, 1998).

A huge increase in the scale, pace, and effectiveness of policy initiatives and measures will be required to change course to a sustainable path

The same report, however, points to major gaps in international discussions of certain economic sectors - namely, energy, transport, and tourism. With energy arguably being the most critical link between the environment and development, the tensions between the legitimate needs of developing countries for socioeconomic development and the health and pollution issues arising from the use of conventional fuels have been inadequately addressed. More focused analysis and action are required, including efforts that enable developing countries to acquire the energy they need for their development while reducing their dependence on carbon-based fuels (clause 129).

The UN Secretary-General's report recognises the plight of the more than 2 billion people with little or no access to commercial energy supplies (clause 11), and identifies poverty eradication throughout the world as a priority for sustainable development (clause 120). The report emphasises the need for an integrated approach and for better policy coordination at the international, regional, and national levels. It points out that since the Earth Summit the debate has focused on the complementarities between trade liberalisation, economic development, and environmental protection (clause 50). Technology partnerships and arrangements to stimulate cooperation between governments and industry at the national and

international levels are needed (clause 135). But the report claims that there has been notable progress on industry-government partnerships and on the development of innovative policy instruments - with greater consideration by governments of cost-efficiency and effectiveness - and environmentally efficient technologies (clauses 89 and 90).

The report considers the increase in regional trading arrangements to be another positive feature (clause 10). The increase in private capital flows in the 1990s (particularly relatively stable foreign direct investments) is highlighted (clause 101), but this is qualified by the fact that these mainly went to a relatively small number of developing countries (clause 13). Indeed, many countries and people have failed to share in the development and growth since the Earth Summit. Debt burdens have hampered the development potential of many low-income countries. Official development assistance from industrialised countries has generally been a grave disappointment for potential recipients. And technology flows to developing countries have "not been realized as envisaged at [the Earth Summit]" (clause 105). Limited progress has been made with economic instruments intended to internalise environmental costs in the prices of goods and services (clause 134). The report soberly pronounces that "much needs to be done to ensure that sustainable development is understood by decision makers as well as by the public", and states that there is a need for adequate communications strategies (clause 118).

The Programme for the Further Implementation of Agenda 21, adopted by the UN General Assembly Special Session in June 1997, echoes many of these sentiments (Osborn and Bigg, 1998). It recognises that overall trends for sustainable development were worse than five years earlier (clause 4). It dwells at greater length on the need to strengthen cooperation and coordination between relevant UN institutions, and states that there is a particular need to make trade and the

environment mutually supportive within a transparent, rule-based multilateral trading system. The programme argues that national and international environmental and social policies should be implemented and strengthened to ensure that globalisation has a positive impact on sustainable development (clause 7). The programme recognises that fossil fuels "will continue to dominate the energy supply situation for many years to come in most developed and developing countries" and calls for enhanced international cooperation - notably in the provision of concessional finance for capacity development and transfer of the relevant technology, and through appropriate national action (clause 42). The programme also recognises the need for international cooperation in promoting energy conservation and improving energy efficiency, expanding renewable energy use and research, and developing and disseminating innovative energy-related technology (clause 45).

To advance towards sustainable patterns of production, distribution, and use of energy at the intergovernmental level, the programme states that the UN Commission on Sustainable Development will discuss energy issues at its ninth session in 2001, with preparations beginning two years in advance. The commission was established to review progress in the implementation of Agenda 21, advance global dialogue, and foster partnerships for sustainable development. The programme sponsored by the UN General Assembly Special Session recognised that the commission had catalysed new action and commitments, but that much remained to be done.

Indeed, the informed study by Osborn and Bigg (1998) concludes that there was a gulf between the rhetoric offered by many world leaders who addressed the UN General Assembly Special Session in June 1997 and the more 'prosaic' document that was agreed in their name. The authors also found that public attention and political will to tackle these issues constructively and cooperatively seemed to have diminished since the Earth Summit. In particular, industrialised countries - with a few exceptions - had

failed to deliver on their promise to make new and additional resources available to developing countries to enable them to handle their development in a more sustainable way. But the authors noted that the UN Commission for Sustainable Development and the UN Department of Economic and Social Affairs had "been able to make some significant improvements in the five years since Rio, and to give sustainable development a key role in the whole structure of UN bodies" (pp. 19-20).

The critical challenge is finding ways to use energy resources at reasonable costs and in ways that do not damage the environment.

Many of the themes and comments made during the deliberations on sustainable development, including the finding that "overall energy trends remain unsustainable" (clause 10), are still applicable. Sustainable energy policies proceed by consideration of, and agreement on, the basic strategy and its purpose - to contribute to sustainable development, introduce policies aimed at implementing the strategy, and implement policy instruments (see table 12.1).

Responding to the challenge of widening access

Drawing on the objectives identified by the Brundtland Commission (WCED, 1987) - itself drawing on earlier studies - and from commitments made at subsequent UN conferences, the first priority of energy policy should be to satisfy the basic needs of the one-third of the world's people without modern energy services. While the scale of this challenge seems enormous, it may not be as great as is commonly perceived. For example, the primary energy required to satisfy the cooking needs of 2 billion people -

by providing access to relatively clean modern cooking fuel - has been estimated at 5 exajoules a year, or less than 1.5 percent of world commercial energy consumption. The electricity required to satisfy basic needs is also relatively small (see chapter 10). In fact, relatively high levels of energy services could theoretically be provided to those currently relying on traditional fuels without major increases in primary energy consumption. That could happen if sufficient emphasis were given to making modern energy carriers and energy-efficient conversion technologies widely available.

Absolute poverty is the fundamental obstacle to widening access. The world's poorest 1.3 billion people live on less than $1 a day and consume only 0.2 tonnes of oil equivalent per capita, mostly as biomass. The only way to foster the necessary investments in situations where poverty precludes the normal operation of energy markets is a combination of a major increase in transfers from industrialised to developing countries and a determined effort to mobilise the often substantial potential of domestic savings in developing countries. Providing every person in the world with a minimum of 500 kilowatt-hours of electricity in 2020 would require additional investment of $30 billion a year between 2000 and 2020 (WEC, 2000). If industrialised countries were to fulfil their agreed commitment to allocate 0.7 percent of their GDP to official development assistance (instead of their recent performance of about 0.2 percent, on average), this additional sum would be readily available.

But official development assistance is expected to continue to be inadequate as long as there are concerns that recipients are using the funds for other purposes - such as military conflicts, payments into private bank accounts, and prestige projects of doubtful value to the community at large. As South African President Thabo Mbeki put it in his New Year's 2000 address: "We must say enough is enough - we have seen too many military coups, too many wars. We have had to live with corruption. We have seen our continent being marginalised." The improper use of official development

assistance is also likely to inhibit the creation and satisfactory performance of the institutions needed to encourage the accumulation and sound use of domestic savings. For official development assistance and the successful mobilisation of domestic savings, it seems essential that all parties firmly commit to ensuring that funds are used for sustainable development projects in energy and other fields. Otherwise it will be difficult to break the vicious circle that exists in too many needy countries.

Access to affordable commercial energy is necessary but insufficient for rural development, and is most effective when integrated with other rural development activities to improve water supply, agriculture, and transport. Key components of the overall strategy for widening access, discussed in more detail in chapter 10, include:

- **Improving access to modern, efficient cooking fuel. This is important both to reduce the time and effort spent using traditional fuels and cooking devices, and to reduce the environmental impacts at the household level, which have particularly pernicious effects on women.**

- **Making electricity available both to satisfy basic needs and to support economic development. Even small amounts of electricity can greatly improve living standards and facilitate income-generating activities, not least in rural areas (see chapter 10). Historically, most needed electricity has been provided through grid extension. Most rural electrification projects have been the result of cooperative efforts and public loans. The main barriers have been private monopolies (which, with few exceptions, regarded rural electrificationas unacceptably costly; see Hughes, 1983 and Nye, 1990), government support for state-owned monopolies (which undermine the efforts of rural cooperatives; Smallridge, 1999), and public interventions in private and cooperative efforts marked by incompetence, vacillation, and disregard for the needs of investors**

and the value of investments already made (Poulter, 1986; Hannah, 1979). But historically, as today, there are examples of successful public-private partnerships. Some rural electrification projects have been subsidised by urban electricity users, but this appears to have been of modest significance. More encouraging are the demonstrable benefits of shifting the responsibility for rural electrification to private cooperatives (as in Bangladesh since 1980), establishing effective partnerships (as with Eskom in South Africa for grid extension to urban and rural customers and for off-grid solar photovoltaic power), breaking up inefficient monopolies, and introducing new regulatory frameworks. (For the historical record on these developments, see Ballin, 1946; Bowers, 1982; Hannah, 1979; Hughes, 1983; Nye, 1990; Parsons, 1939; Poulter, 1986; Schlesinger, 1960; Shapiro, 1989; and Smallridge, 1999.) Local circumstances should always be taken into account, however. Between 1970 and 2000 the number of rural residents in developing countries with access to electricity jumped by 1.1 billion (chapter 10). Yet the number without access seems to have remained much the same in 2000 as in 1990 - 1.8 billion (Davis, 1995). The main reason is that rural population growth greatly exceeded electrification in South Asia and Sub-Saharan Africa (World Bank, 1996). Extending grid-based electricity supplies in rural areas can cost seven times as much as in urban areas, where load densities are low. And even where rural load densities are high, the cost is likely to be 50 percent higher than in urban areas (World Bank, 1996). Thus decentralised, smaller-scale solutions are being sought. Since 1987 more rural households in Kenya have received electric lighting from an unsubsidised solar photovoltaic programme than from the heavily government-subsidised rural electrification programme.

- **Addressing the challenges of growing urban populations. Large urban**

populations in some developing countries result in large numbers of people living a marginal existence, suffering from widespread poverty and uncertain employment and incomes. In the 1990s more than 30 percent of the urban population in many developing countries lived below the national poverty line. More than 400 million urban residents of developing countries lack electricity. Whereas 46 percent of the world's population was urban in 1996, by 2030 the share is projected by the UN to reach 60 percent. Africa's urban population, which was about 250 million in 1996, may reach 850 million by 2030. In Latin America the figure is expected to rise from 350 million to 850 million; in Asia from 1.25 billion to 2.75 billion. Much of the increase is anticipated to come from a rural exodus propelled by population growth, poverty, and lack of employment opportunities. Growing urban population will also be a major factor, occurring largely among the poorer sections of the community. (All these projections may have to be modified if the ravages of AIDS prove higher than currently anticipated.) Whereas grid connection will be a relatively attractive option for extending electricity supplies to urban dwellers, affordability will be a major issue. The experiences of Eskom in South African townships and Electropaulo in So Paulo, Brazil, indicate that well-designed schemes and partnerships can make a major contribution to addressing these challenges.

• Providing decentralised options. This is gaining greater attention in the search for ways to increase access to electricity in rural areas, and more options are becoming available. Options for decentralised electricity generation include diesel-engine generator sets (recently beginning to be deployed in Sub-Saharan Africa), mini-hydropower, photovoltaics (being deployed in Botswana, Kenya, Mozambique, and South Africa, as well as in numerous Asian and Latin

American countries), windpower (India's windpower capacity reached 1,077 megawatts at the end of 1999, and China's reached 300 megawatts, up 34 percent from the end of 1998), and small-scale biomass gasifier engine-generator sets (see chapter 10). There have been problems with system reliability, and the need for guaranteed performance standards has been highlighted in a number of project evaluations - especially for solar home systems. Lack of sufficient capital to purchase equipment, and costs of imported equipment (especially where import duties and value added taxes are levied, and where the 1997-99 East Asian financial crisis had a devastating impact on foreign exchange rates), have also been recurring issues. Microturbines (using natural gas or diesel fuel) are believed to have considerable potential (chapters 8 and 10). Liquefied petroleum gas (LPG), heating oil (both kerosene and fuel oil), and biogasifiers using anaerobic fermentation technologies (China is a world leader in this field) are other decentralised options. When used in stoves for cooking, LPG, biogas, and kerosene are several times more efficient than wood (see figure 10.1) and are friendlier to the local environment. Among the conditions for success of these alternatives to traditional fuels are good marketing and after-sales service (including the necessary infrastructure), and the avoidance of inhibiting price caps and regulation (see chapter 11 for details on experiences with LPG markets in Brazil and India). A coordinated institutional approach and community participation are also required.

- **Financing rural energy. Rural residents often pay more for commercial fuels (kerosene, LPG, diesel, gasoline) than do urban dwellers. They often need help meeting the high initial costs of switching to energy carriers (including the devices required for their use) that are higher on the energy ladder, and**

ultimately less expensive. By providing people with access to credit, rapid service improvements can often be obtained at relatively low cost and without resorting to subsidies (which are often counterproductive).

- **Developing new institutional structures and partnerships for providing rural energy services. New institutional forms will be required to deliver rural energy services in ways that are consistent with the more competitive conditions to which energy systems are evolving. One option would be to issue rural energy concessions that oblige concessionaires to serve, in the least costly ways, all rural residents with clean cooking fuels and electricity at levels adequate to meet basic needs. Efforts have been made to support relevant schemes by providing financial help to systems dealers and suppliers and to participating banks; dealers and suppliers in turn offer instalment plans to users. The results have been mixed. (After an encouraging start, for instance, Indonesia's Solar Home Systems Project ran into difficulties starting in 1997, after the onset of the Asian financial crisis, and was terminated in 2000). Nevertheless, the need for innovative systems is clear, given the shift from conventional energy carriers with relatively few actors and large supply-side structures to new systems with a multitude of small, scattered installations manufactured, distributed, marketed, and operated by numerous individuals or small firms. In this context it is interesting to note that more than 10 million people borrow from microfinance programmes world-wide, although this remains a young industry (World Bank, 1999c, p. 128).**

Improving environmental acceptability

Given the degree to which human civilisation has already altered the planet, environmental protection is no longer a luxury. Rather, it is critical to maintaining the

health of the ecosystems on which we all depend. Minimising the adverse environmental impacts of energy use is essential for sustainable development. Thus much of this chapter deals with how environmental acceptability can and should be improved, by incorporating environmental costs into markets, by improving end-use efficiency, and by spurring the development of new technologies with fewer adverse impacts.

Competition may be hampered by too few players or too few new entrants, or by market distortions that give advantages to some players.

Chapters 2 and 3 provide compelling evidence on why the adverse environmental impacts of energy use must be reduced if human living standards and prospects are to be improved. Indoor pollution, transport emissions, other urban pollution (including precursors to tropospheric ozone formation, which has a radiative forcing effect), and acid deposition have been highlighted in this report as pressing problems. Gains have been recorded in industrialised countries, with some indicators of air, water, and land showing improvement past degradation, along with lower emissions of sulphur, lead, and particulates. But most of these gains are corrections of past practices. A much cheaper approach for countries in early stages of development would be to leapfrog directly to the cleanest modern technologies possible, thereby avoiding the mistakes of today's industrialised countries. A number of technology options that combat local and regional pollution also mitigate global climate change. Because all countries stand to gain from this, encouraging technological leapfrogging and leadership in developing countries should be a major focus for international cooperation.

In addition to local and regional pollution, threats to the global environment are arousing growing concern. Energy use associated with the combustion of fossil fuels is the main source of anthropogenic greenhouse gas emissions, which are widely believed to be damaging the global climate (chapter 3) and threatening further temperature rises. There are, however, some promising technological options that can mitigate climate change (chapter 8). (Global climate change is addressed in greater detail below, in the section on more effective cooperation.)

Many, but by no means sufficient, initiatives are being taken to improve environmental acceptability. These include:

- **The introduction of better cooking stoves to reduce indoor pollution (chapters 2, 3, and 10).**

- **Energy efficiency measures (see chapter 6 and section below on raising energy efficiency).**

- **Efforts to encourage new renewable energy deployment (as in Argentina, Botswana, Brazil, China, Costa Rica, Denmark, the Dominican Republic, Finland, Germany, Honduras, India, Indonesia, Kenya, Mexico, Morocco, the Philippines, South Africa, Spain, Swaziland, Sweden, the United Kingdom, and the United States; see also chapters 7 and 10).**

- **Cleaner fossil fuel provision and use (as with coal washing, sulphur abatement, and reduced particulate emissions in China and India).**

- **Carbon sequestration (such as injecting separated carbon dioxide into depleted oil and natural gas formations, and into subsea aquifers under the**

North Sea; or diverting recaptured carbon dioxide from coal-fired electricity generating plants.

Making markets work better

Markets are more effective than administered systems in providing innovative and affordable products, securing needed finance and investment, and achieving consumer satisfaction (box 12.2). Markets mainly operate through competition and price signals, and thus have a built-in ability to adjust to changes in supply and demand. They encourage learning through continuous provision of relevant information and choices. A recurring message of this report is that, within the energy sector, market processes are preferable to 'command and control' approaches. To the extent possible, policy initiatives should focus on helping markets operate more effectively and more widely.

Markets never work perfectly, however. Competition may be hampered by too few players or too few new entrants, or by market distortions that give advantages to some players. In many countries competition is relatively new in the energy sector or has not been introduced. Yet even if markets were working well in these respects, they are widely regarded as unable to address issues of equity, and externalities of health and the environment, unless market reforms include measures to address the public benefits concerns associated with these issues.

BOX 12.2. WHY ELECTRICITY SUPPLIES ARE UNRELIABLE WHEN MARKETS ARE DISCOURAGED FROM FUNCTIONING

In many places, especially in developing and transition economies, markets work poorly. As a result electricity supplies are highly unreliable and have high attendant costs.

In addition to the 2 billion people who rely on traditional fuels for cooking, about as many suffer from highly unreliable supplies. World Bank data on transmission and distribution losses in many developing and some transition economies reflect this. Frequent blackouts and brownouts can be life-threatening and result in severe economic losses and social disruption. Large Nigerian companies spend about 10 percent of their capital investment on standby generators. In smaller companies standby generators account for nearly 30 percent of capital investment. Such diversion of investments imposes a heavy cost on businesses and their customers (ADB, 1999).

Among the reasons for unreliable, inefficient, and low-quality service are:

- Lack of competition (usually due to the predominance of inefficient monopolies).
- Lack of investment (reflecting difficulties in agreeing on adequate returns or in retaining or repatriating earnings).
- Poor maintenance.
- Competing financial priorities (most governments are now unwilling to provide investment capital for energy projects to state-owned companies).
- Lack of the discipline of competition, which fosters economic efficiency.
- Low priority accorded to customer service.

By introducing competition, improving regulation, imposing penalties for non-performance, offering higher and more secure returns to investors, and exposing inefficiency and corruption, considerable progress can be made in achieving reliable supplies. In essence, this means making markets work better and ensuring that competition is effective.

Markets often fail to support sustainable energy systems because of the short-term horizons of business and investor decision-making (which takes into account interest and discount rates and perceived risks) relative to the long-term challenges of sustainable energy development. Government initiatives often have a short-term orientation as well. New regulations may be required to ensure fair competition and advance public benefits, including meeting the needs of vulnerable customers, protecting the environment, and facilitating the deployment of innovative energy technologies that help in the pursuit of sustainability goals. This section discusses policies that can make markets work better to deliver sustainable energy. The rest of the chapter deals with targeted policies needed to deal with gaps that markets, under current conditions, do not fill.

An 'uneven playing field' is one of the biggest barriers to the widespread implementation of sustainable energy strategies. This means that some competitors enjoy an unfair advantage, true competition is not occurring, new entry is inhibited, and market forces cannot operate effectively. In the energy sector, markets and prices are distorted by widespread subsidies for fossil fuels (often introduced to benefit the poor or to encourage growth, but frequently achieving neither goal effectively) and by a failure to account for externalities. If subsidies were phased out, and externalities fully reflected in energy prices, market forces could achieve many of the aims of sustainability.

Internalising externalities

Free market prices do not reflect the full social and environmental costs resulting from commercial and industrial activities. Since it does not receive these pricing 'signals', on its own the market will not lead to optimal investments from a societal perspective. Including social and environmental externalities in energy prices is, in principle, an

elegant way to address many issues of sustainability. But in the real world it proves difficult, for practical and political reasons.

Finding ways to figure externalities into energy prices is problematic because there is no consensus on how to measure their costs (for a more detailed discussion of cost-accounting externalities that affect health and the environment, see chapter 3). These costs are substantial but, as chapter 11 emphasises, not insuperable.[3] Environmental economists have been proposing appropriate techniques for many years (such as willingness to pay to avoid and willingness to accept environmental intrusion at a negotiated or estimated price; or hedonistic pricing). Chapter 7 argues that, in principle, carbon dioxide taxes are the simplest and most consistent method for internalising the cost of mitigating climate change. Others favour a mix of energy and carbon taxes as a way to curb a wider variety of energy-linked externalities. One advantage of a mix of taxes - which could include taxes on hydropower and biomass as well as fossil fuels - is that it would encourage end-use efficiency for all energy users and reflect the wider range of adverse social and environmental impacts implied by different forms of energy. Various countries have introduced policies aimed at integrating externalities into energy prices. For example, six Western European countries (four of them in Scandinavia, which has a higher tolerance for taxes for social purposes than most countries) have introduced taxes on carbon emissions or fossil fuels along revenue-neutral lines.[4] The United Kingdom plans to introduce a climate change levy on industry in April 2001 - but with relief for the heaviest emitters (the details have been greatly changed from those originally announced due to lobbying by interested parties) - and a sliding-scale emissions charge on company-owned vehicles in April 2002. Proposals for a carbon tax have been tabled in Switzerland. These countries already have implicit carbon taxes on gasoline exceeding $100 per tonne of carbon dioxide (Baranzini, Goldemberg, and Speck, 2000, table 1).

Residential energy consumption generally escapes such tax innovations, undermining their effectiveness. The industrial sector in OECD countries has demonstrated significant emission reductions over many years but continues to be the target for emissions reduction taxation. As a general rule, however, the heaviest emitters attract the greatest relief.

BOX 12.3. CARBON TAXES

A carbon tax is a charge on each fossil fuel proportional to the quantity of carbon emitted when that fuel is burned. Carbon taxes have often been advocated as a cost-effective instrument for reducing emissions.

Carbon taxes (and emission taxes in general) are market-based instruments because, once the administrative authority has set the tax rates, emissions-intensive goods will have higher market prices, lower profits, or both. As a result market forces will spontaneously work in a cost-effective way to reduce emissions. More precisely, taxes have two incentive effects. A direct effect, through price increases, stimulates conservation measures, energy efficient investments, fuel and product switching, and changes in the economy’s production and consumption structures. An indirect effect, by recycling the fiscal revenues collected, reinforces the previous effects by shifting investment and consumption patterns.

In addition to emission and carbon taxes, other taxes affect emissions from energy use, though this may not be their stated intention. For example, carbon emissions are already implicitly taxed in most countries - even in those that do not have explicit carbon taxes. The implicit carbon tax is the sum of all taxes on energy, including taxes on energy sales (excise duties). Because such taxes are not proportional to carbon content, their efficiency is impaired as carbon taxes. There are three other problems with carbon taxes - their impacts on competitiveness, on the distribution of the tax burden, and on the environment.

The impact on competitiveness is the main perceived obstacle to the implementation of carbon taxes. Yet empirical studies on carbon and energy taxes seem to indicate that they do not have a significant impact on either losses or gains.

On the distributive impacts of carbon and energy taxes, empirical studies (almost entirely confined to industrialised countries) indicate that there is an expectation that carbon taxes will be regressive. But available studies are almost equally divided between those that support this expectation and those that do not.

As far as environmental impacts are concerned, empirical studies evaluating the reductions of carbon dioxide emissions resulting from carbon taxes are rather limited. Moreover, the reduction in local pollution associated with a decrease in fossil fuel consumption represents an additional benefit from carbon taxes, but it is not always mentioned and studied in detail. However, carbon dioxide is not the only greenhouse gas that can be emitted as a result of human activities, nor is it the only one emitted in energy use. All anthropogenic greenhouse gases should, in principle, be encompassed in policy measures, by levying taxes proportional to their estimated global warming potentials.

The introduction of and adjustments to carbon taxes can be greatly facilitated by starting with a small levy along with the announcement that the tax will be gradually increased by specified increments at specified intervals. This approach gives energy users time to adjust their patterns of investment and use of energy-using devices to less carbon-intensive and more efficient ones, minimising economic disruption.

Carbon taxes are an interesting policy option, and their main negative impacts can be compensated through the design of the tax and the use of the generated fiscal revenues. Consideration can also be given to shifting the imposition or collection of such taxes from downstream (consumers or importing governments) to upstream (producers or exporting governments) to offset the implied diversion of income that would otherwise result, in keeping with article 4.8 (h) of the UN Framework Convention on Climate Change.

Source: Baranzini, Goldemberg, and Speck, 2000.

Box 12.3 discusses the dynamics and economic implications of carbon taxes in greater detail. An alternative approach is greenhouse gas emissions trading - nationally (along the lines of sulphur dioxide emissions permit trading in the United States) or internationally (as proposed in article 17 of the Kyoto Protocol). This alternative is frequently preferred by those who dislike new taxes or who are sceptical that revenue authorities will use revenues for their intended purposes. There are numerous examples of revenues from road vehicle taxes, intended to expand and upgrade road infrastructure, being diverted for general public spending. A recent example comes from the Netherlands, where revenues from a fuel tax introduced in 1988 were initially earmarked for environmental spending - but in 1992 the fuel tax was modified and revenues were no longer earmarked (Baranzini, Goldemberg, and Speck, 2000).

The logic has also been questioned of exempting energy or emission taxes on raw materials processing and heavy industrial energy activities involving high emissions, as is now widely the case. If the real objective is to reduce emissions, then full imposition of energy or emission taxes on the heaviest emitters can be expected to make a major contribution to achieving that goal. It may encourage early and major shifts in the use of certain materials and products, and in attitudes and behaviour, needed to effect emission reductions but which exemptions are likely to frustrate. In pursuing such an intellectually rigorous policy, steps may need to be taken to discourage relocation of heavily emitting activities ('carbon leakage'), including barriers in international trade rules to the import and use of the resulting materials and products to ensure global benefits.

Phasing out subsidies to conventional energy

A second issue to consider in achieving true competition is the significant subsidies for conventional energy that still exist in many economies - industrialised, transition, and developing. These publicly supported subsidies may be granted to producers, consumers, or both, and can take various forms. Their common feature is that they distort market signals and, hence, consumer and producer behaviour. Although subsidies are being cut in many countries, they are still believed to account for more than $150 billion a year in public spending (excluding the transport sector; see World Bank, 1997c; Hwang, 1995; Larsen and Shah, 1992 and 1995; Michaelis, 1996; de Moor, 1997; Myers, 1998; Ruijgrok and Oosterhuis, 1997).

Russia slashed fossil fuel subsides by about two-thirds between 1991 and 1996. China is also phasing out fossil fuel subsidies. They have already been cut by 50 percent and now effectively remain only on coal, at a much lower rate. (Moreover, between 1997 and early 2000 China closed more than 50,000 coal mines, so recent policy initiatives and economic conditions have resulted in a significant fall in carbon dioxide emissions from coal combustion.) As explained in chapter 11, conventional energy subsidies have been found to be financially unsustainable as well as largely counterproductive - because they often do not go to the most needy, and generally prolong inefficiency and harmful emissions throughout the energy chain.

In many countries subsidies for conventional energy coexist with incentives for conservation and new renewable energy development. Some subsidies may be partially hidden - as with preferential tax rates on domestic fuel and power use, incentives to use private motor vehicles (such as free or subsidised fuel and parking), and fiscal measures that have the least impact on the heaviest users. In addition to working at cross-purposes to the aims of sustainable development, subsidies often

impose a substantial financial burden, especially in developing countries. The under-pricing of electricity in developing countries was estimated to result in annual revenue shortfalls of more than $130 billion by the early 1990s (World Bank, 1996).

Some countries ostensibly maintain energy subsidies to help poor people. But other approaches may be more effective, particularly since subsidies intended to help the poorest people often deliver the most benefits to richer and heavier users. Investing in insulation for homes, for instance, could achieve the same result as subsidising heating fuel for the poor. But investing in insulation would have additional and longer-lasting social benefits (reducing greenhouse gases, creating jobs). Innovative credit schemes can be more cost-effective than subsidies in terms of extending energy services to the rural poor. In general, subsidies to reduce kerosene or electricity prices benefit richer and heavier users. For example, diesel subsidies to better-off farmers may cause excessive pumping of water for irrigation, seriously lowering the water table. Agricultural electricity tariffs in India have long caused particular concern, being at times little more than 3 percent of those in Bangladesh and only 6-15 percent of those in a number of other Asian countries (World Bank, 1996).

If carefully designed, however, schemes providing the very poorest members of society with a small quantity of electricity (say, 50 kilowatt-hours per household per month) free of charge or at a very low cost offer a workable and effective way of helping poor people (see chapter 6). This approach has worked well in So Paulo, Brazil, where Electropaulo (the local electricity utility) and the city authorities agreed in 1979 to bill consumers a subsidised flat rate for minimal monthly consumption of 50 kilowatt-hours. By the late 1980s electricity consumption per shack had increased to 175 kilowatt-hours a month - and many of the dwellings and the quality of service had improved, with an array of social benefits (Boa Nova and Goldemberg, 1998). In addition, well-designed temporary subsidies may be needed to speed sustainable

energy innovations to the point of commercialisation, after which time the subsidies should be phased out (see chapter 11 and the section below on the rationale for public policy support).

Six Western European countries have introduced taxes on carbon emissions or fossil fuels along revenue-neutral lines.

Regulatory options for restructured energy sectors

Recent and ongoing changes in the electricity and natural gas sectors are altering the long-accepted ground rules for ownership, operation, management, and financing of utilities. For several decades, energy supply systems were regarded as being necessarily large to achieve economies of scale and support massive capital investments. This view encouraged the idea that energy supply systems required the creation and support of natural monopolies, that duplication was economically inefficient, and that the public interest could be protected only by state-owned and -operated monopolies. Over the years subsidies proliferated, biases in favour of large and highly visible projects became evident, innovation stalled (often reflecting an unwillingness to access the best available technologies from elsewhere), management was found wanting, external finance became problematic (due to inefficiency and administrative interventions), and strains on government budgets escalated. The assumption that electricity generation and distribution were a natural monopoly - whether publicly or privately controlled - eventually began to be revisited, and industrialised and developing countries alike have begun to restructure their energy

sectors to encourage competition and improve economic efficiency.

One major problem facing policy-makers in a number of developing countries, especially in Sub-Saharan Africa and some Southeast Asian countries, is that options for liberalisation suffer from several constraints. Breaking up a public monopoly often results in substitution by a private monopoly. Domestic savings and investment institutions either do not exist or are inadequate for requirements. And external finance is difficult to attract. Any monopoly is likely to create problems of poor efficiency, choice, and quality of service, so strict regulations need to be put in place and the monopoly broken up or subjected to competition from new entrants wherever possible. External support may be needed for capacity building that focuses on institutional creation and reform. Political stability and a welcoming investment regime are the usual means by which external finance is best attracted. Studies of World Bank projects show that where the macroeconomic fundamentals of low inflation, limited budget deficits, and openness to trade and financial flows are adhered to, projects are more successful. But projects also require the participation of beneficiaries and the support of governments (World Bank, 1999d).

The encouragement of competition and efficiency is leading to a widening of the playing field and a decentralisation of systems, allowing the forces of competition to work more effectively. Introducing competition in the energy sector tends to lower costs and increase consumer satisfaction. At the same time, competitive pressures can make it more difficult for energy suppliers to support public benefits (such as clean air or research, development, and deployment) through cross-subsidies or other means. The introduction and effective implementation of consistent policies and measures for market players can, however, provide the opportunity for balancing efficiency and supporting other public benefits.

By itself energy market restructuring may not help achieve the long-term vision compatible with sustainable energy policies and their successful application. For instance, market liberalisation and privatisation are claimed to have slowed rural electrification in Latin America - although this judgement appears speculative given that liberalisation and privatisation were only just getting under way in Latin America by 1997 (OLADE, 1997). Restructuring is unlikely to encourage the promotion of energy forms with high front-end costs - such as current nuclear power technologies and large hydropower schemes. In Argentina and Brazil market reform is expected to encourage natural gas at the expense of electricity generated by large hydropower schemes, raising greenhouse gas emissions. In the United Kingdom market liberalisation and privatisation have encouraged natural gas over nuclear energy. (The same pattern is expected in Germany.)

The market reform process, however, provides a window of opportunity for introducing reforms that facilitate the introduction of sustainable energy technologies. Energy market restructuring should also serve as a reminder that a number of public benefits were not addressed in the non-competitive electricity and gas sectors in many countries. (The situation was often different in the downstream oil sector.)

Although energy sector liberalisation tends to make energy services more affordable (though there have been some countries where this has not been the case), it requires the establishment of a regulatory framework to foster other public benefits. The basic characteristics of energy sector liberalisation include:

- **Industry restructuring, most often involving the unbundling of vertically integrated activities to permit power to be transported and traded by more independent entities.**

- **The active promotion of competition and private sector cooperation.**

- **Deregulation and reduction of barriers to new entry.**

- **Commercialisation (or corporatisation) of state-owned entities and, increasingly, their privatisation.**

- **Industry restructuring, most frequently involving the unbundling of vertically integrated activities to permit power to be transported and traded by more independent entities.**

- **The establishment of a regulatory framework.**

Achieving greater energy efficiency generally requires less investment than does new generation.

Unlike liberalisation, privatisation may not be necessary to make energy markets more efficient. In Norway, for example, most electric utilities are publicly owned (more than half by municipalities and some 30 percent by the state). But since the 1990 Energy Act, there has been a transition to a fully deregulated market at both the generation and retail levels, allowing individual producers and customers to act as independent sellers and buyers. The system uses negotiated bilateral agreements, maximum five-year futures contracts negotiated on a weekly basis, spot market purchases with market-determined prices fixed for the next 24 hours, and instant market purchases

for delivery with as little as 15 minutes' notice (York, 1994). However, Norway is the most frequently cited instance where electricity prices have risen for consumers since liberalisation.

Unbundling of vertically integrated activities has widely been regarded as essential for competition. For instance, competition among electricity generators and suppliers (including energy service companies) has usually been introduced for large industrial customers, then spread gradually to households. The separation of transmission and distribution networks from providers (generators and suppliers) has also generally marked a major redefinition of electric utilities. Finally, retail competition may be marked by service providers seeking to bundle together various services - taking advantage of the databases and information technology at their disposal (initiatives that regulators tend to watch carefully lest earlier dominant positions are abused).

While restructuring has, by and large, contributed to lower energy costs, it is not clear how good a job it will do in protecting all desired public benefits. For that to occur effectively, it may be useful for policy-makers to work with the private sector to develop regulatory measures to advance public benefits in the context of a restructured, global, and more competitive environment. Some countries are taking advantage of the window of opportunity opened by restructuring to consider various funding mechanisms associated with energy use to pursue public benefits. Options include regulatory measures to allow prices to reflect the level and structure of the marginal cost of supply, including the costs of compliance with environmental policies. This, in turn, would allow industry to attract finance and to earn satisfactory returns on investments, including the investments required to comply with environmental policies.

Regulations could also require companies to report on progress with the extension of

supplies to unserved populations, in much the same way that progress with environmental protection is monitored. But it is clear from Norway's experience that, whether market reforms involve privatisation or continued public ownership, they are unlikely to protect or advance public benefits unless accompanied by specific regulatory measures to that end. In framing policy to cover this wider range of objectives, it is likely to remain important that the primary duty of competition regulators is to maintain and further competition. In many countries there is also a need to find ways of financing extensions of energy carriers to areas not currently considered attractive to private investors.

Two types of policy initiatives have recently been introduced by some countries to address the public benefits issue (apart from programmes to raise energy efficiency and reduce local and regional pollution):

- **Measures to support renewable energy development by obliging utilities to buy or sell a minimum proportion of energy from renewable sources.**

- **Systems benefits charges (also known as a public benefits fund), which raise revenue from a 'wires charge' that is then used for public goods programmes such as assisting energy use by low-income households or promoting energy efficiency, renewable energy, and research and development.**

One of the most successful examples of an obligation to buy, in terms of capacity created, is Germany's windpower development programme, introduced under its 1991 Electricity Feed Law. (However distribution utilities raised strong objections to the premium prices they had to pay - which they were not permitted to pass on to consumers - and the resulting financial burden. The law was modified in 2000 to permit costs to be passed on.) By the end of 1999 Germany's windpower capacity

stood at 4,444 megawatts, up from 2,875 megawatts at the end of 1998.

In the United Kingdom a non-fossil fuel obligation (which in its early years overwhelmingly went to subsidise nuclear power, and proved rather disappointing in expanding windpower capacity) is not being retained. Instead, a renewables obligation is requiring licensed electricity suppliers to supply customers with a specified proportion of their supplies from renewable sources. A cap will be placed on the maximum price paid for renewables, to minimise the impact on consumer prices, and suppliers will be permitted to fulfil their obligation through the purchase of 'green certificates'. Concern has been expressed, however, about the limited penalties for non-compliance implied. The U.K. government hopes to raise the renewable energy component of electricity supply from 2.5 percent today to 5 percent by the end of 2003, to 10 percent by 2010 (DETR, 2000). There are widespread concerns about the feasibility of these targets and non-compliance, given the low share of 'green' electricity in the United Kingdom relative to most other EU member countries (Runci, 1998).

Denmark has successfully pursued a renewables obligation for utilities, to the point that windpower capacity stood at nearly 1,740 megawatts at the end of 1999 and a successful international business in wind turbines had been achieved. Power market reforms introduced in 1999 will, however, move Denmark to a programme of both renewables portfolio standards and systems benefits charges.

In the United States renewables portfolio standards have obliged electricity suppliers to include a stipulated proportion of renewables-based electricity in their supply mix. The U.S. experience, for instance with windpower development, has been mixed. But in 1999 there was a surge in U.S. windpower capacity, from 1,770 to 2,500 megawatts. The extension of the Federal Production Tax Credit to January 1, 2002, is

expected to help maintain rapid expansion of windpower capacity. Buyers have also been signing up for green power in increasing numbers - particularly in California, where customer incentives were funded by the state's restructuring legislation. These incentives were so successful that by late 1999 steps had to be taken to reduce the subsidy before the state ran out of funds. The best-known programme of systems benefits charges also exists in California, where it was introduced in 1996. (The wires charge on electricity entering California's transmission and distribution system is $0.003 a kilowatt-hour, or about 3 percent of the average tariff.) The Clinton administration proposed making such a scheme - a public benefits fund - applicable throughout the United States under an electricity restructuring bill.

In Brazil new concessionaires following privatisation are required to spend 1 percent of their (after-tax) revenues on energy conservation - and 0.25 percent specifically on end-use measures. These requirements will provide considerable support to PROCEL, Brazil's national electricity conservation programme.

In summary, key regulatory options to encourage sustainable energy include:

- **Measures to widen competition - for example, by guaranteeing independent power producers access to power grids and giving energy service companies opportunities to bid on supply contracts.**

- **Allowing prices to reflect marginal costs of supply.**

- **Obligations to serve specific regions in return for exclusive markets (concessionaire arrangements).**

- **Obligations to buy (such as renewables portfolio standards, which help bring**

down the cost of clean new technologies).

- **Creating a public benefits fund (for example, through a wires charge) to support wider access, or the development and diffusion of sustainable energy technologies.**

- **Energy efficiency and performance standards.**

- **Reporting requirements to ensure transparency.**

Raising energy efficiency

From a societal perspective, achieving greater energy efficiency generally requires less investment than does new generation, and it means fewer energy-related environmental externalities. From an individual perspective, it can mean significant savings over the long term. Why, then, do energy efficiency measures not achieve their cost-effective potential, even in market economies? As noted, markets do not work perfectly, and market barriers for energy efficiency measures are many, including:

- **Lack of information, technical knowledge, and training.**

- **Uncertainties about the performance of investments.**

- **Lack of capital or financing possibilities.**

- **High initial and perceived costs of more efficient technologies.**

- **High transaction costs.**

- **Lack of incentives for maintenance.**

- **Differential benefits to the user relative to the investor (for example, when monthly energy bills are paid by the renter rather than by the property owner).**

- **Consumer patterns and habits (such as inertia, convenience, and prestige).**

As shown in chapter 6, large reductions in primary energy requirements can be made cost-effectively using current technologies to provide energy services. Even greater savings can be realised using advanced technologies. Seeking to capture the full economic potential for energy efficiency improvements is desirable in order to benefit from the lower cost of providing energy services, to free economic resources for other purposes, to reduce adverse environmental impacts, and to expand fuel mix flexibility.

Evidence suggests that more than 60 percent of the primary energy initially recovered or gathered is lost or wasted in the various stages of conversion and use. More than 60 percent of this loss or waste occurs at the end-use stage (Nakicenovic, Grbler, and McDonald, 1998); hence the importance of the discussion in chapter 6. In a similar exercise for the Intergovernmental Panel on Climate Change, almost 71 percent of primary energy was calculated as wasted or 'rejected' (Watson, Zinyowera, and Moss, 1996). Furthermore, there is even greater theoretical potential for energy efficiency that goes beyond the first law of thermodynamics (to the concept of exergy) and that suggests global end-use efficiency is only 3.0-3.5 percent (WEC, 1993).

Raising the efficiency with which energy is provided and used is a common objective for energy specialists and policy-makers, and is a strategy that can work synergistically with each of the other strategies discussed here. Raising energy efficiency, especially at the point of end use, eases the apparent conflict between

energy as a public good and the negative impacts of energy use. It may also be a more politically realistic way of achieving reductions in energy consumption than persuading individuals to change consumption patterns. It is frequently suggested that in richer, market-driven societies, changes in attitude and behaviour would greatly reduce energy consumption. In principle this is true. But it is extremely difficult to get people to change their life styles. Desired results may be more readily obtained by lowering primary energy consumption significantly while maintaining the quantity and quality of energy services provided - namely, through energy efficiency improvements. Ideally, a two-pronged approach should be adopted.

Clear energy-using appliance labelling schemes are an important first step in providing information on energy efficiency, and on the efficiency of other resource use where appropriate (as with water use in washing machines and dishwashers). Tighter performance standards together with labelling can greatly enhance the energy efficiency of end-use appliances such as refrigerators, washing machines, and videocassette recorders. Tighter performance standards and measures to discourage avoidable use can greatly improve the energy efficiency and environmental performance of motor vehicles. A number of countries would claim to engage in demand-side management, a term used in the U.S. electricity sector, to provide a comprehensive approach to raising energy efficiency. A more piecemeal approach has been the reality. Moreover, few countries are applying consistent and pervasive standards in road transportation.

Western Europe, with high taxes and duties on gasoline (and in some cases carbon taxes) and widespread emission controls, comes closest to a consistent and effective policy framework. The often-cited Corporate Average Fuel Economy (CAFE) standards applied to light-duty vehicles in the United States since 1975 made a major contribution to fuel economy until the late 1980s (reinforced by a tax on 'gas guzzlers'

in the 1980s) and encouraged conservation. But these achievements were undermined in the 1990s by the growing popularity of sports utility vehicles and people carriers with size and fuel consumption characteristics that place them in the category of trucks. (In the Ford Excursion, Chevrolet Suburban, and Dodge Durango, for example, fuel consumption of about 12 miles a gallon is not unusual.)

A number of developing countries are taking steps to raise end-use efficiency in building, lighting, and appliance uses. In the early 1980s China introduced an energy efficiency programme (including financial incentives) that is the largest such programme ever launched in a developing country. Overall energy intensity fell 50 percent between 1980 and 1987, helped by this programme - although, even with steady gains since, intensity remains much higher than in industrialised and many developing countries. Some countries are using energy audits to raise efficiency in industrial, commercial, and governmental uses of energy; Egypt has been doing so since 1985. A growing number of developing countries are deploying labelling schemes and efficiency standards. Brazil's PROCEL programme (introduced in 1986), Mexico's CONAE programme (introduced in 1989), and more recent programmes in the Republic of Korea and the Philippines offer significant examples. Thailand's main energy efficiency scheme is funded by customers through a levy. In a five-year project, initial targets have already been greatly exceeded for lighting, refrigerators, and air conditioning. The key elements are educating consumers and labelling appliances, and the Thai utility (EGAT) has played a key role in both elements (see also the final section of chapter 6, on policy measures).

In several transition economies in Central and Eastern Europe and in the Russian Federation (along with Denmark and Finland) efforts to increase energy efficiency have, in principle, long been enhanced by district heating systems. During the 1990s numerous efforts were made to upgrade these systems, in some cases with the

support of energy service companies. But it has been difficult to attract the necessary investment and to have confidence that end-use efficiency will be maximised. A major barrier is getting individual apartments metered, largely because of the costs of installing individual meters. This has resulted in buildings continuing to be metered as a single unit, which gives residents of individual apartments less incentive to cut their use of heat and power. But many transition economies have taken more general efforts to raise energy efficiency, including through lower subsidies and higher prices. One example is Poland, where GDP increased 32 percent in 1990-98 but primary energy consumption fell 23 percent.

There are a number of ways of addressing the 'least first-cost' barrier and other barriers to ensuring that energy efficiency is accorded higher priority in decision-making. One is through voluntary agreements intended to ensure that business and industry are proactively involved. As has been seen in Germany, the Netherlands, and the United States, voluntary agreements by and with business and industry can pay considerable dividends - provided that participants genuinely support the initiative and do not seek it as a means of avoiding actions that would otherwise have been required under regulatory approaches. In assessing the likely viability of voluntary agreements, importance is usually placed on the local political and cultural climate of industry-regulator relationships (Wallace, 1995). A second approach is through tighter public procurement policies. Public procurement policies can prioritise more efficient buildings and end-use devices, but few countries have taken this very far or formally. The scope for change is large. Since 1993, for example, the U.S. Energy Star labelling scheme has raised the energy efficiency of computer hardware with considerable success and increasing international collaboration.

BOX 12.4. IMPROVING ENERGY EFFICIENCY AND REDUCING EMISSIONS IN THE

TRANSPORT SECTOR

A discussion of energy efficiency policy options would not be complete without reference to the transport sector. The on-road fuel intensities of automobiles in Australia, Canada, and the United States remain high relative to those in Western Europe. Automobile fuel intensity is also somewhat higher in Japan and rose between 1985 and 1995 (see figure 6.3).

Light-duty vehicle energy use is highly sensitive to changes in vehicle use and fuel efficiency. A sensitivity analysis conducted for the United States and Canada in a World Energy Council (WEC) report on global transportation anticipates that by 2020 light-duty vehicle energy use could be 300-512 million tonnes of oil equivalent (mtoe) - a difference of more than 40 percent (Eads and Peake, 1998). Perhaps even more important for global energy use by the transport sector is whether the developing world follows the U.S. pattern of relatively high light-duty vehicle fuel intensity and vehicle use, or the pattern of Western Europe. The WEC sensitivity analysis showed that if the latter course were pursued, global light-duty vehicle energy demand could be 350 mtoe, or 27 percent below the base case projection - and only 27 mtoe above the 1995 level. This would imply a savings of 300 million tonnes of global carbon emissions in 2020 relative to the base case projection. Most analysts believe that higher fuel prices reduce vehicle use and encourage motorists to purchase more fuel-efficient vehicles. Gasoline taxes in Western Europe range from about $2.50 to more than $4.00 a gallon.

The WEC study did not explore the longer-term potentials of alternative fuels in general or of fuel cells in particular. Although fuel cells could begin entering the transport market by 2010, the impact at the global level will be modest by 2020. Beyond 2020, however, there is considerable potential for major change.

There are also close links between transport and urban and rural planning. An obvious planning option is to design urban systems to maximise the accessibility of efficient collective transport modes (as was done in the often-cited example of Curitiba, Brazil, although further development is increasing strains even there). Another option is to discourage out-of-town developments that impel more personal vehicle use and undermine the viability of urban and suburban centres. Similarly, planning systems can discourage piecemeal development in rural areas that increases use of personal motorised vehicles and road freight.

In 1995 road freight accounted for 30 percent of global transport energy demand, and that share is expected to rise in the next few decades. Among the policy options for containing that change are maintaining or increasing the shares of rail transport and water-borne freight. That requires policy measures to improve rail and shipping infrastructure, and subsequent measures to discourage road transport for competing routes and journeys, especially in urban areas. Air passenger transport, which accounted for 8 percent of global transport energy demand in 1995, is expected to increase its share sharply through 2020. The WEC report on global transport included a base case projection of energy demand growing at nearly 4 percent a year, increasing air passenger energy demand to 13 percent of the transport total. Policy-makers will wish to consider the many implications of this expansion both at ground level and in the air, not least because of the complex interactions between the environment and aircraft flying at high speeds in or close to the lower stratosphere. Airfares do not reflect the many environmental costs of air travel. Transport policy options include:

- Raising vehicle fuel efficiency and lowering use, thereby reducing light-duty vehicle fuel intensity - particularly in Australia, Canada, Japan, and the United States.

- Applying full-cost pricing and rigorous emission and fuel efficiency standards on all vehicles, with specific policies targeting unnecessarily high fuel use (for example, from four-wheel drive vehicles used by urban motorists and from low-occupant journeys by ‘people carriers’).

- Encouraging the introduction and deployment of advanced transportation technologies that offer high efficiency, low emissions, and opportunities for fuel diversification.

- Promoting alternative fuels, including investments in fuel delivery infrastructure.

- Adjusting fuel prices to achieve the above goals.

- Encouraging a shift to Western European (rather than U.S.) driving patterns in developing countries.

- Improving effectiveness and consistency of urban and rural planning.

- Promoting bus and rail use and supporting related infrastructure.

- Facilitating pedestrian and pedal-cycle journeys.

- Maintaining rail and water-borne modal shares for freight transport.

- Monitoring passenger aircraft use for land-use and other environmental impacts.

Even after new technologies for greater efficiency and more pollution control are introduced, they take years to achieve full market penetration. (It takes 15 years for a full turnover of stock in OECD countries, and substantially longer in developing countries.) Thus policy actions initiated now will take years to have a significant effect on the environment.

A third approach was adopted by the National Board for Industrial and Technical Development (NUTEK, replaced in 1998 by the Swedish National Energy Agency). The board convened consumers to learn about their needs in terms of efficient appliances.

By indicating the existence of a market for such appliances, this effort encouraged producers to satisfy those needs with equipment of improved efficiency and performance. Significant results were achieved for refrigerators and freezers, lighting, windows, heat pumps, and washing machines.

There is considerable further potential for taking a sectoral approach to raising the efficiency of energy use. One such area is construction materials and building design. Since 1978 Switzerland has gone to great lengths to ensure that architects, builders, and materials suppliers are aware of the issues at stake. Building design competitions can also be used to heighten awareness. The transport sector poses particular challenges, and has an evident need for clearly focussed policy responses (box 12.4; see also chapter 6).

Mobilising investments in sustainable energy

Cumulative global energy investments required in 1990-2020 are estimated at $9-16 trillion. The lower figure reflects a major drive towards energy efficiency and new renewables, as in case C in chapter 9. The higher figure reflects the challenges of meeting the higher-growth case A. At constant 1990 prices these figures imply energy investments of $300-550 billion a year, which is within the range of current investment levels. The lower investments estimated for case C offer an important rationale for aiming for this rich and green future, rather than towards the higher-growth case A (assuming the estimates are robust).

The investments required to achieve case C represent less than 10 percent of recent global domestic investment (estimated at more than $6 trillion in 1997) and would be much less than 10 percent of total global investment over 2000-20. Thus the amounts are not large relative to the finance available for investment, either internationally or

as implied by the high domestic savings ratios in many developing countries.[5] The challenge, then, is not so much to conjure the capital into existence, but to mobilise what already exists. But this challenge has been described as severe - particularly in developing countries, because of political instability, an absence of reliable savings and investment institutions, the wariness of savers and investors, unreliable legal procedures, and the high incidence of political and administrative intervention (WEC, 1997). In some countries corruption is also a problem (World Bank, 1997d, ch. 6). All these features are liable to have an adverse impact on access to credit for parastatal energy companies, international corporations, domestic private enterprises, and individual consumers.

Many developing country governments, in particular, still need to allocate sufficient public funds to meet investment needs, attract sufficient funds from elsewhere, and underwrite energy activities. Many countries have problems accessing capital for political or institutional reasons (or both), and poor and needy developing countries, as well as a significant number of transition economies, are among the weakest in terms of political stability and institutional frameworks. In some of these countries political risks, absence of the necessary institutional frameworks and effective legal remedies, and prevalence of arbitrary interventions pose powerful barriers to investment and successful project completion. The result, as the programme adopted by the UN General Assembly Special Session in June 1997 recognises, is that "conditions in some of these countries have been less attractive to private sector investment and technological change slower, thus limiting their ability to meet their commitments to Agenda 21 and other international agreements" (clause 21).

BOX 12.5. CONDITIONS CONDUCIVE TO ATTRACTING FOREIGN DIRECT INVESTMENT IN THE ENERGY SECTOR (AND OTHERS)

- Political and economic stability, to provide reasonable predictability and reduce the risk of non-performance.
- A functioning legal framework, including currency convertibility, freedom to remit dividends and other investment proceeds, and a stable domestic savings and investment regime.
- A regulatory regime that promotes competition and efficiency and that, once created by government, is independent of and protected from arbitrary political intervention.
- Necessary physical infrastructure.
- Availability of, or capacity to supply from elsewhere, technical skills, goods and services, and a trained and trainable workforce.
- Availability of all the above to all companies and investors through law and general practice, without the need for recourse to special deals or treatment or discretionary decisions by elected officials or bureaucrats.

Source: WEC, 1997.

Several industrialised countries have developed bilateral insurance schemes to address the problems of political risk and non-performance, although in many instances at a considerable financial cost for the scheme and for taxpayers in the investing country. The Multilateral Investment Guarantee Agency (part of the World Bank Group) provides long-term investment guarantees against political risks in Eastern Europe and Central Asia. The role of this agency has been questioned in some quarters. But there have been suggestions that a multilateral global energy fund should be created to cover political risks and facilitate needed energy projects.

Experience suggests that some fairly straightforward conditions need to be met for successful project realisation with or without political risk infrastructure, and they are not confined to the energy sector (box 12.5).

Thus financing remains a daunting challenge for many of the countries and areas that need sustainable energy systems the most. Public investments are increasingly difficult to finance as governments respond to pressures to balance budgets. Market reforms and the creation of functioning legal frameworks (which include not only laws but also strong and fair judicial systems to enforce them) are moving slowly in many countries. Businesses, households, and small communities may wish to carry out projects that are too small to attract standard bank lending, so financial incentives and credit arrangements may be important for project viability. More extensive use of private initiatives, cooperative schemes, and public-private partnerships will be required, and new forms of partnership considered, to sustain long-term investment programmes designed to deliver energy to rural areas (see chapter 10). Investors should be encouraged to work with governments and financial institutions to extend commercial energy services to populations in developing countries as rapidly as possible.

A major challenge will be to find ways to facilitate the widespread deployment of new, clean, and efficient energy technologies in developing and transition economies. One suggestion is that this task become the main energy-related activity of the World Bank, since the main traditional energy activity of the Bank - financing conventional energy projects - cannot easily be justified under the reformed market conditions to which most developing countries are evolving. (Under such conditions the World Bank would compete for financing contracts with commercial banks, which will be fully capable of providing the needed capital.) It has also been suggested that the Global Environment Facility (GEF) allocate more resources to capacity and institution

building, as part of the improvements in the disbursement of funds called for in UN documents (see Osborn and Bigg, 1998, pp. 112 and 173). In June 1997 the UN General Assembly Special Session pointed out the need for the GEF implementing agencies - UNDP, the United Nations Environment Programme, and the World Bank - "to strengthen, as appropriate and in accordance with their respective mandates, their co-operation at all levels, including the field level" (clause 79; see Osborn and Bigg, 1998, p. 173).

Earlier in the year the UN Secretary-General had recognised UNDP's Capacity 21 Programme as "an effective catalyst and learning mechanism to support capacity-building for sustainable development" (clause 108; see Osborn and Bigg, 1998, p. 114), and in June 1997 the UN General Assembly Special Session asked UNDP to give this priority attention through, among other things, the Capacity 21 Programme (clause 99; see Osborn and Bigg, 1998, p. 180). In May 1999 a strategic partnership between UNDP and GEF was agreed and a start made on producing a comprehensive approach for developing the capacities needed at the country level to meet the challenges of global environmental action. This has become the Capacity Development Initiative (CDI), which will have three stages: assessment of capacity development needs (a questionnaire for this purpose was being evaluated in April 2000), strategy development to meet identified needs, and action plans for GEF. So far the focus appears to have been on biodiversity, desertification, and climate change because these are the three most relevant UN conventions in existence. But consideration should be given to specific consideration of energy capacity development needs.

The World Bank has been active in promoting capacity building over a wide area of activities, including the Global Knowledge Partnership and its knowledge management system, both of which are relevant to promoting advanced energy technologies (World Bank, 1999c). In addition, institutional arrangements such as the Clean Development

Mechanism proposed under the Kyoto Protocol could help disseminate clean new energy technologies in developing countries.

Multilateral agencies have been criticised for their expensive, time-consuming, and complicated procedural requirements - yet these agencies are often the only source available for financing rural electrification and renewable energy projects in emerging markets. In addition, the smaller size of these projects often means that they cannot receive the allocation of staff from the agencies, which focus on large power projects (usually fossil-fuelled). Financing procedures are usually geared towards large national projects, and place costly burdens on smaller renewable energy projects. Review standards may be more stringent and time-consuming for small renewable projects, with innovative technologies, than for well-defined large fossil fuel plants. It has been suggested that a fast-track process for one stop financing be instituted for renewable energy projects. The process should incorporate a short review period, a restricted number of financing participants with a team leader, agency teams assigned to projects from beginning to end, standard project agreements for renewable projects, and a closing schedule agreed at the outset (Bronicki, 2000). This would help reduce transaction costs and project costs, provide more energy services sooner, and foster more efficient and cost-effective financing operations of multilateral agencies.

Financing procedures are usually geared towards large national projects, placing costly hurdles on smaller renewable energy projects.

Attracting private capital

Encouraging private investment in the supply of sustainable energy carriers to developing countries is essential for two reasons. First, many governments no longer wish (and may not be able) to provide the needed capital investment (see above). Second, multilateral and other official lending institutions are unlikely to provide more than 15 percent of the funding required for energy investments over the next few decades (WEC, 1997, p. 75).

Thus a high priority should be placed on the types of reform required to attract both domestic and foreign private capital at the country level. Foreign direct investment by private companies is an important and growing share of net resource flows to developing countries. Official development assistance fell by about 20 percent (in real terms) during the 1990s, and represents a shrinking fraction of net resource flows. In 1997 official development assistance represented only about 15 percent of net resource flows to developing countries, down from 43 percent in 1990. In contrast, foreign direct investment expanded rapidly in the 1990s. In 1998 foreign direct investment rose 39 percent, to $644 billion. Of this, $165 billion went to developing countries (UNCTAD, 1999).

But most foreign direct investment - 70 percent in 1998 (World Bank, 1999c) - goes to just 10 countries, rather than to the much larger number in serious need. In 1997 the main recipients were China (31 percent), Brazil (13 percent), and Mexico (7 percent). Nevertheless, the World Bank (1999a, p. 47) has reported that foreign direct investment is less volatile than other forms of capital inflows. For instance, during the 1990s foreign direct investment was less volatile than commercial bank loans or total portfolio flows (World Bank, 1999d, p. 37). This is in keeping with the findings of the UN Secretary-General’s report of January 1997 and the UN General Assembly Special Session programme of June 1997 (see above, in the section on policy goals; Osborn and Bigg, 1998).

In many ways the history of the oil and gas industries illustrates how private enterprise, working within an established system of concessions around the world, has been able to attract significant and sufficient capital investments to fund energy exploration, production, and distribution. In many countries these functions have been carried out through public-private partnerships. Private-private joint ventures are also common, and have led to efficient operation and transfer of technologies.

In many countries the conditions for attracting foreign direct investment are unlikely to be met in the near future (see box 12.5). In such cases public-private partnerships may offer an alternative structure to encourage foreign investment in energy projects. In a public-private partnership the two sides bring a wider range of concerns and capabilities to the table. Given a competitive framework, private sector participation will tend to increase economic efficiency. The public sector, on the other hand, has an obligation to protect other public benefits. The combination can increase the political acceptability of conditions that lead to private investment. Adequate returns and tolerable risks are, however, a precondition for private investment. In some institutional arrangements - such as joint ventures between publicly and privately owned corporations - the best of both sides may be harnessed. Examples exist in Argentina, the Dominican Republic, Honduras, Mexico, the Philippines, and South Africa.

Tapping other sources of funding

Where private financing is not available, developing countries must turn to other sources. Domestic policies, as well as the broader policy environment in which financing and lending decisions are made, will have an impact on the ability of developing countries to finance sustainable energy initiatives.

For example, financing at reasonable interest rates is often critical for the successful diffusion of end-use energy efficiency and renewable energy measures. Innovative credit schemes are facilitating the adoption of off-grid household solar photovoltaic systems in many developing countries, with mixed results. Multilateral development banks have contributed to many of these programs, as in India and Indonesia. Although much has been made of the need for microcredit - with Bangladesh's Grameen Bank the most often-cited example of a microcredit institution - the availability of funds falls far short of needs. Few microcredit schemes operate specifically to finance sustainable energy projects. Since 1974 the Grameen Bank has successfully loaned money in small amounts to many people (particularly women) for economic and social development purposes. And in recent years Grameen Shakti (Energy) has been lending money for modern energy schemes - solar photovoltaic and windpower - though it still operates on a small scale. Still, with more than 10 million people now benefiting from microcredit facilities for all purposes, there is potential for making greater use of such schemes in promoting sustainable energy development.

Historically, the vast majority of energy loans from development banks went to large-scale hydropower, fossil fuel, and traditional energy infrastructure projects. Very little funding was devoted to energy efficiency or smaller-scale renewable energy technologies. Recently, however, the development banks have begun to shift the balance of their activities. In 1994-97 the World Bank approved $1.2 billion in loans for energy end-use efficiency projects, efficiency improvements in district heating systems, and non-traditional renewable energy projects. This is equivalent to about 7 percent of World Bank energy loans during this period (World Bank, 1999c). Furthermore, the Bank had another $1.5 billion in energy efficiency and renewable energy loans scheduled for approval in 1998-2000. This is a positive trend. The Asia Alternative Energy Program (ASTAE) within the World Bank provides a useful model

for promoting energy efficiency and renewable energy technologies. ASTAE's mission is to give greater priority to such projects and technologies within the Bank's activities in Asia. Major loans have been approved for China, India, Indonesia, and other countries in the region, in many cases together with grant funding from GEF or bilateral donors for training, capacity building, and market development. By the end of 1998 ASTAE had helped develop and obtain approval for 24 projects involving $750 million in World Bank loans and GEF grants (ASTAE, 1998).

While new technologies hold great promise, their development and diffusion is not occurring quickly enough or at a large enough scale to meet the challenges of sustainability.

GEF was created to help developing countries pay the incremental costs of technologies with significant global environmental benefits. But to date GEF has operated largely on an ad hoc project-by-project basis. GEF is starting to work systematically on some advanced energy technologies - for example, through its fuel cell programme and photovoltaic market transformation initiative. But closer links between GEF and the private sector will be required to broaden such initiatives.

New forms of international public finance have been suggested as ways of addressing the declining share of official development assistance to developing countries and promoting sustainable development. A variety of proposals have been put forward for raising revenue for these purposes, ranging from an international carbon tax to charges for using the global commons. The suggested advantage of such taxes is their

potential to raise large sums of money automatically - that is, without continuous funding cycles and voluntary commitments. Their disadvantage, as seen by the main revenue-raising authorities and taxpayers, is lack of control over how the money is spent and dissent over its allocation.

This raises the sensitive subject of conditionality in official development assistance and other financial and technology transfers. Where finance provided for sustainable development has been (or is being) used for other purposes, there may be legitimate grounds for donors to apply ex ante or ex post conditions to additional finance. To encourage flows of the funding needed for sustainable development, this topic needs to be discussed more openly between developing and industrialised countries. Initiatives such as the erasure of the external debt obligations of heavily indebted poor countries could include rules on future funding and credit allocation that foster efficient and environmentally friendly energy technologies.

Some other relatively new options have had trouble achieving their objectives because of reluctance by governments and bureaucracies to establish and maintain mutually satisfactory conditions. In recent years many developing countries have tried to introduce privately financed electrification projects by guaranteeing markets to independent power producers in exchange for new generating capacity. In this they have followed an approach based on experience in the United States, following the Public Utility Regulatory Policy Act of 1978. But the conditions that made independent power producers attractive in the United States have changed. With the opening of the U.S. electricity market, many utilities are unwilling to sign long-term power purchase agreements (WEC, 1997).

A number of projects involving independent power producers in various countries have run into problems for the following reasons:

- **Authorities failing to allow market-based prices.**
- **Poor credit ratings of agencies contracting to purchase the power.**
- **Exposure to political risks.**
- **Excessive debt-equity ratios.**
- **Inability to raise sufficient equity.**
- **High foreign exchange risks.**
- **Efforts by the authorities to control rates of return.**

The East Asian financial crisis of 1997-99 created additional obstacles to the introduction of independent power producers. Since then, however, interest has revived in such producers.

Build-own-transfer (BOT) and build-own-operate-transfer (BOOT) schemes have also been attempted, with varying success. In such projects a developer owns the plant for a limited period, after which the asset is transferred to a utility (usually under government control and ownership). Because the plant is usually planned to have no residual value to the investor at the end of the fixed period, the returns on the investment in the early years, and the price of electricity from the plant, will have to compensate. This makes BOT and BOOT schemes relatively costly and complicated options. Moreover, an independent power producer's investment in such schemes is unmarketable, so risks cannot be spread, shares cannot be sold, and an opportunity to develop local capital markets is lost (WEC, 1997). Where BOT and BOOT schemes do take off successfully, it is usually due to the provision of government guarantees, which are essentially a form of public procurement and credit. Such schemes can have the benefits of putting projects in place, using modern technology, and building local capacity. But their relative costliness and complexity remain a barrier, and the time limitation can inhibit capacity building.

Following the scope for joint implementation of policies and measures between parties to the UN Framework Convention on Climate Change, introduced under the convention's article 4.2(a), more than 130 projects have been brought forward, although the issue of crediting has not been resolved. (This led to the introduction of the phrase 'activities implemented jointly' - without crediting - at the first conference of the parties to the convention in 1995.) The Kyoto Protocol seeks to take this further with projects that supplement domestic action, especially under the Clean Development Mechanism and in keeping with the sorts of action consistent with article 2 of the protocol (for example, promoting efficiency, new and renewable forms of energy, carbon dioxide sequestration technologies, and advanced and innovative environmentally sound technologies).

Encouraging technological innovation for sustainable energy development

Chapter 5 shows that limited energy resources are not expected to constrain development. But meeting the demands of sustainability will require major improvements in the efficiency of energy use, a much higher reliance on renewable energy technologies, and cleaner and safer fossil fuel technologies. While much can be accomplished through the wider deployment of commercial technologies, new technologies are also needed. Chapters 6-10 point out that while new technologies hold great promise, their development and diffusion is not occurring quickly enough or at a large enough scale to meet the challenges of sustainability. Thus there is a need to accelerate the energy innovation process through all effective means, including appropriate public policies where these can be identified.

The energy innovation chain has four stages: research and development (R&D), demonstration, early deployment, and wide-spread dissemination. Each stage has distinct requirements, faces barriers, and involves policy options for seeking to

overcome those barriers. These characteristics are summarised in table 12.2 and described in more detail in the remainder of this section.

While there is widespread agreement on the need for a smooth transition through all links in the chain, different observers have different opinions about the problems. Researchers active at the beginning of the chain, whether or not reliant on external grants and contracts, may highlight the dangers of bottlenecks in the early part of the chain. Those who are more market-oriented - being engaged in the development and sale of products using the resulting technologies - are likely to focus on the severe barriers to wide-spread dissemination, and the desirability of gaining higher priority for sustainable energy technologies, with which this chapter is primarily concerned.

In considering policy initiatives to support energy R&D, some profound issues need to be addressed. For instance, a school of thought believes, based on a careful review of U.S. experience, that government support has often been profoundly inconsistent with successful R&D projects (such as photovoltaics), causing the projects to suffer from "highly unstable annual budgets" (Cohen and Noll, 1991, p. vii). On the other hand, some unsuccessful projects (such as the Clinch River Breeder Reactor) "have continued to receive support long past the time when the project was clearly destined to fail, because of inflexibilities in project design and political imperatives" (p. vii). This school of thought has concluded that "these problems are inherent in long-term, risky investments by the government, and thus constitute an argument for favouring generic research activities rather than large-scale commercialization projects" (p. vii). In this view R&D programmes are more likely to succeed the less fragmented is responsibility for them across agencies and Congressional committees (Cohen and Noll, 1991).

Additional lessons can be learned from the U.S. federal programme intended to make

synthetic fuels from coal. Cohen and Noll and their colleagues identified three main reasons for failure that are liable to be replicated in future government programmes for energy R&D. The first is the risk that government makes decisions based on short-run circumstances and point projections from very speculative projections, or knee-jerk reactions. Second, cost estimates are liable to demonstrate their proponents' ubiquitous optimism about undeveloped processes. Third, the synthetic fuels programme demonstrated the difficulty of government support for long-term commercial development - an expensive development programme was required but needed a strong, stable coalition of political interests to support it and substantial benefits for lobbying interests such as the industry, technology providers, or consumers. The programme did not have such sustained support. Many observers believe that the first two reasons for failure arise only when there is an effort to substitute government (taxpayer) funding for private risk capital in commercialisation projects. The U.S. experience has important parallels in some other industrialised countries. Ideally, therefore, a smooth transition through the energy innovation chain should be aimed at, and government support should focus on generic research.

Understanding the energy innovation chain

Before they can reach commercial readiness, new energy technologies, building designs, and infrastructure need several years to decades (depending on the technology) for research, development, and demonstration. And once they become commercially ready, these technologies typically require decades of market growth to achieve major market shares (Grbler, 1998). The juxtaposition of such long lead times against the urgency of moving towards sustainable development goals underscores the need for smooth and, where needed, accelerated progress along the energy innovation chain for promising technologies. The practical implementation of this perceived need nevertheless has to take into account:

• The time profiles of capital stock turnover (which vary according to the type of capital item under review) and the extent to which economic and political barriers may constrain the pace of turnover.

• The significance of fundamental research relative to incremental R&D.

• The amount being spent on energy R&D under its various subheadings - and the cases where it can reliably be claimed that more should be spent on environmentally sound technologies or on areas where growth rates (and therefore capital stock expansion or turnover) are fastest.

Most ongoing innovative activity is for incremental improvements in technologies (such as combined cycles) already established in the market. Where there has been substantial progress with radically new technologies, it has, in a number of high-profile and important instances (such as gas turbine and nuclear technologies), been based on past government-supported activities for which support has subsequently declined. Although some radically new technologies will be needed to meet sustainability goals during the 21st century (along with wider application of already well-developed environmentally friendly ones), it is uncertain which will prove to be the most affordable, convenient, safe, and environmentally benign. Chapter 11 points out that when uncertainties are large, it makes economic sense to invest in creating options and reducing uncertainties and costs. Policies that encourage technological innovation also open the door for unexpected side benefits.

Clean and efficient end-use energy technologies are somewhat different. These can often be developed and marketed over much shorter periods because they involve briefer re-investment cycles, and thus greater opportunities for short-term change. Control techniques, appliances, production machinery, and automobiles offer such

opportunities. Here public policies that focus on incentives, including stable macroeconomic fundamentals (which promote innovation under competitive conditions), may be appropriate.

TABLE 12.2. THE ENERGY INNOVATION CHAIN FOR SUSTAINABLE ENERGY TECHNOLOGIES

	Research and development (laboratory)	Demonstration (pilot to market)	Early deployment (technology cost buy-down)	Widespread dissemination (overcoming institutional barriers and increasing investment)
Key barriers	• Governments consider R&D funding problematic • Private firms cannot appropriate full benefits of their R&D investments	• Governments consider allocating funds for demonstration projects difficult • Difficult for private sector to capture benefits • Technological risks • High capital costs	• Financing for incremental cost reduction (which can be substantial) • Uncertainties relating to potential for cost reduction • Environmental and other social costs not fully internalised	• Weaknesses in investment, savings, and legal institutions and processes • Subsidies to conventional technologies and lack of competition • Prices for competing technologies exclude externalities • Weaknesses in retail supply financing and service

				• Lack of information for consumers and inertia • Environmental and other social costs not fully internalised
Policy options to address barriers	• Direct public funding (national or international) • Tax incentives • Incentives for collaborative R&D partnerships	• Direct national or international support for demonstration projects • Tax incentives • Low-cost or guaranteed loans • Temporary price guarantees for energy products of demonstration projects	• Temporary subsidies through tax incentives, government procurement, or competitive market transformation initiatives	• Phasing out subsidies to established energy technologies • Measures to promote competition • Full costing of externalities in energy prices • 'Green' labelling and marketing • Concessions and other market-aggregating mechanisms • Innovative retail financing and consumer credit schemes • Clean Development Mechanism (see text)

Source: Adapted from PCAST, 1999.

The arguments in favour of accelerating the introduction of inherently clean and safe energy-converting and energy-using technologies are often as relevant for developing countries as for industrialised ones. For that reason it is desirable to extend the scope of energy R&D so that a significant fraction is directed to meeting the needs of the developing world, which will account for most of the world's incremental energy requirements (see chapter 9). Major shifts will almost certainly be required globally, because today nine OECD countries account for more than 95 percent of the world's publicly supported energy R&D (Dooley and Runci, 1999a). Simply importing advanced technologies from industrialised countries - even if affordable - is unlikely to suffice, although adjustments based on local conditions and practices may be possible. New energy technologies should be tailored to the resource endowments and specific needs and capabilities of developing countries. Optimising new technologies for developing needs will require significant developing country participation in the energy innovation process.

Although there is much ongoing technological advance,[6] public investment in energy innovation has been falling. In a few countries private spending on energy R&D is low and may be falling as well. In the United States in 1981-96, the energy sector's R&D intensity was extremely low and falling relative to many other sectors (Margolis and Kammen, 1999). This contrasted with a 5 percent annual increase in overall private U.S. investment in R&D in the 1990s (Dooley, 1999b).

But there is also evidence suggesting that private spending on energy R&D has been stable or rising in other countries - such as Finland, Germany, and Japan. A U.K. Department of Trade and Industry survey found that R&D spending by the world's top 300 international companies rose 13 percent in 1997 and 12 percent in 1998, to $254

billion (The Financial Times, 25 June 1999). The oil and gas sectors strongly increased R&D spending in 1996-98, as did most of the leading engineering companies associated with energy. No international comparison was available for electricity, but the same source found that U.K. electricity R&D was 8 percent higher in 1998 than in 1997.

Where spending on energy R&D has fallen off, much of the decline represents decreased funding for nuclear technologies and standard fossil fuel technologies. Some of this funding is now going to advanced cleaner fossil fuel research and carbon sequestration. Funding for renewables has been relatively flat (although this may - and in some cases does - mask large increases in some subsectors, such as solar in Japan). Funding for energy efficiency programmes has been consistently increasing. Even in the United States, widely portrayed as the epitome of collapsing spending on energy R&D, real federal spending on energy efficiency R&D rose 8 percent a year in the 1990s, and real federal spending on renewable energy R&D rose about 1 percent a year (Dooley, 1999b). But the evidence requires careful analysis, as discussed in more detail in the annex to this chapter.[7] Nevertheless, there is concern that spending on energy innovation, from both private and public sources, may prove inadequate relative to the challenges confronting the world in the 21st century (see PCAST, 1997 and 1999; Margolis and Kammen, 1999; and Dooley and Runci, 1999a).

New energy technologies should be tailored to the resource endowments and specific needs and capabilities of developing countries.

One dilemma is how to distinguish between R&D inputs and R&D outputs. Outputs may not flow readily from inputs and may change over time (for instance, due to improvements in computer hardware and software). Another challenge is to account accurately for the R&D outsourcing by mature companies to specialised firms (as anticipated by Stigler, 1968). Furthermore, policy, institutional, and financial barriers inhibit the pace and pattern of technical diffusion. Hence the contention that market conditions are of overwhelming importance.

Although demonstration plants and early production units are often much more costly per unit of installed capacity than plants based on existing technology, the unit cost of manufactured goods tends to fall with cumulative production experience. This usually happens rapidly at first but tapers off as the technology matures - a relationship called an experience curve when it accounts for all production costs across an industry (figure 12.1). Early investments can 'buy down' the costs of new technologies along their experience curves to levels where the technologies may be widely competitive. The three technologies in figure 12.1 have progress ratios of about 0.8, which is close to the historical median for many industries.

Successfully demonstrated technologies that are radically different from existing technologies are typically much more costly than established alternatives. Thus it may be desirable to promote investments aimed at lowering their costs to competitive levels. Strategies are required for overcoming policy, institutional, and end-user financial barriers to the wide dissemination of new sustainable energy technologies that are both proven and cost-competitive. The entire innovation process can be stalled if any link in this chain is weak. Conversely, the existence of strong market demand (pull) can overcome weaknesses earlier in the chain.

The rationale for public policies in support of energy innovation

Schumpeter (1942) pointed out that successful innovators are rewarded with temporary monopoly control over what they have created, and there is an extensive literature on the relatively high returns achievable on R&D spending. Despite these broadly supportive background conditions, there is concern in some quarters that innovation rests on a few players - while imitators who incur few R&D costs prevent the main R&D investors from enjoying the full benefits of their efforts (the 'free rider' problem). This concern has led to the claim that spending on energy R&D is suboptimal.

In other quarters the concern about free riders is principally regarded as a restatement of the nature of innovation, not a justification for public policy intervention. Further action may be more readily justified on other policy grounds, such as the desirability of incentives to encourage specific courses of action. Such incentives can be directed at areas where spending is considered suboptimal. But since it can be countered that moving from the current situation implies opportunity costs, it follows that claims of current suboptimality may be judgmental. Where there has been a major move away from R&D spending on nuclear power and less advanced fossil fuel technologies, towards R&D spending on renewable energy, advanced fossil fuel and carbon sequestration technologies, and energy efficiency - as has happened recently in some countries - this may reflect widespread political and public opinion. In any event, the key issue may be that it is not so much R&D spending in preferred subsectors that is lacking, but diffusion of the preferred technologies that is found problematic for a variety of reasons.

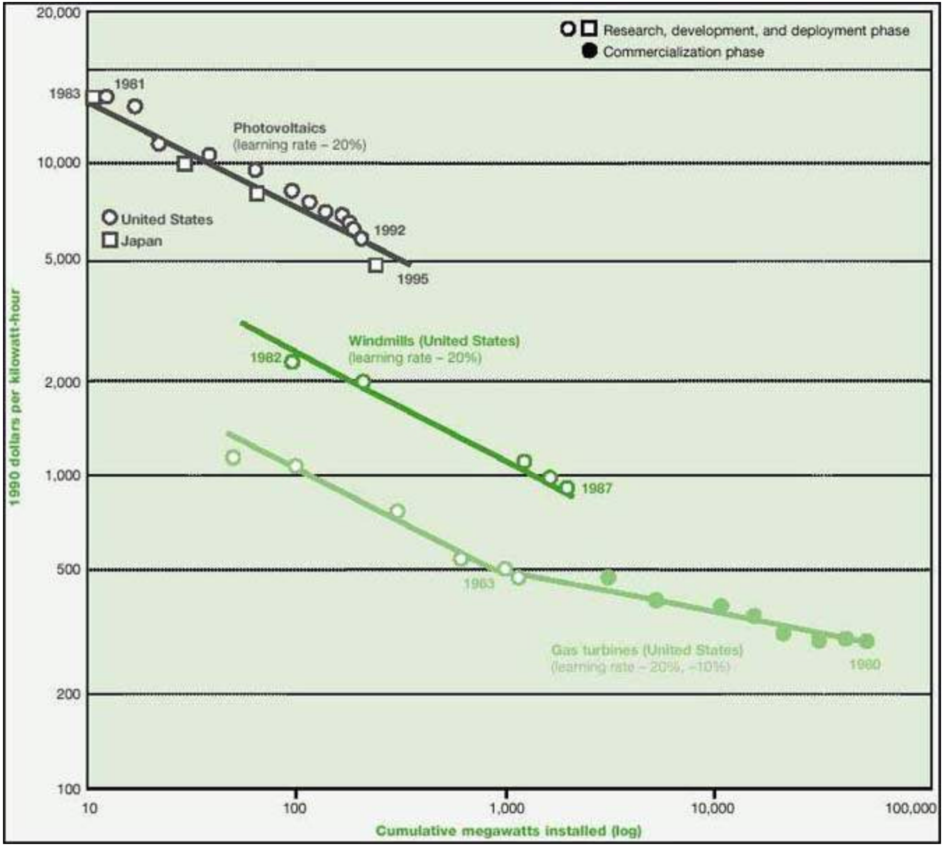

FIGURE 12.1. EXPERIENCE CURVES FOR PHOTOVOLTAICS, WINDMILLS, AND GAS TURBINES IN JAPAN AND THE UNITED STATES

Technology performance and costs improve with experience, and there is a pattern to such improvements common to many technologies. The specific shape depends on the technology, but the persistent characteristic of diminishing costs is termed the 'learning' or 'experience' curve. The curve is likely to fall more sharply as technologies first seek a market niche, then full commercialisation, because lower costs become increasingly important for wider success.

Source: Nakicenovic, Grbler, and McDonald, 1998.

Those actively engaged in or responsible for corporate R&D often dispute claims that private R&D spending is inadequate, and severely constrained by the free-rider problem, on the grounds that they need to - and do - invest in R&D to keep up with competitors and survive. There are many examples within and outside the energy sector where this is the case. But there may also be a grey area where energy companies might gain from making additional R&D expenditures, particularly with a view to using successful results in their daily operations, but are reluctant to move ahead of competitors if extra costs are going to be incurred and competitive gains eroded more quickly than expected returns can justify. The wide range of corporate R&D spending between innovative engineering companies, on the one hand, and energy service providers, on the other, may reflect these differing views.

More cogently, firms may not invest adequately in R&D when innovation is needed to reduce costs not reflected in market prices (such as environmental costs). Public investment in R&D, as well as policies that stimulate private investment in R&D related to sustainable energy goals, may be warranted where there is good reason to believe that private efforts are falling short.

In general, private efforts seem most likely to fall short in long-term research (see chapter 8), where returns may be expected to be particularly uncertain and deferred (and investments open-ended and potentially large). This approach may be entirely rational for private efforts, yet it may not advance the public good. In such cases government support for innovation may be desirable. In the context of using energy provision and use to move towards sustainable development in the long run, government support is potentially of great significance.

There is considerable debate about the appropriate role for government in supporting activities downstream of R&D that involve potential commercial products. One widely held view is that such activities should be left entirely to the private sector. But as noted, the private sector tends to focus its energy innovation investments on incremental changes to existing technologies for which initial prices for new products are not much higher than for existing products (and might even be less). For this and other reasons, some recent studies recommend a major government role in these areas for energy products anticipated to provide significant benefits that are not adequately reflected in market prices (PCAST, 1999; Duke and Kammen, 1999).

There is no guarantee, however, that such government involvement will produce the benefits sought. Indeed, there is a risk - in this as in other public policy areas - that as a result of lobbying for research spending (the technology 'pork barrel'; see Cohen and Noll, 1991 and Savage, 1999, among others), there may be wasteful diversion of taxpayer funds from more urgent or productive uses. Such diversion occurs despite numerous past failures from government interventions of this kind, as indicated at the start of this section.

Policy options for promoting technological innovation

Research and development. Options for government support of R&D include grants and contracts, tax incentives to encourage private R&D, and incentives for national and international collaborations involving various combinations of private firms, universities, and other research institutions.

Demonstration projects. Demonstration efforts to prove technical viability at a near-commercial scale are generally costly, risky, and difficult to finance. The public sector has a poor track record in picking winners; its support for demonstration has rarely led to successful commercial products.[8] The most successful demonstration efforts have been those in which the government role has been limited to setting performance and cost goals and to providing some financial support. The private sector, meanwhile, takes responsibility for technological choices in addressing these goals and shoulders a major share of the needed investment.

Buying down costs. For some radically new energy technologies intended to meet sustainable development goals, public subsidies may be needed and justifiable to facilitate private sector-led efforts aimed at buying down technology costs. Many industrialised and some developing countries offer financial incentives to stimulate new renewable energy development. The need for subsidies is especially great where external costs are not fully internalised in energy prices.

Public resources for technology cost buy-down should be allocated according to criteria focused on maximising societal returns on these scarce funds. Incentives should:

- **Encourage lower technology costs through all possible means - including competition, economies of scale in production, economies of learning through accumulated experience, and gains from making marginal technological**

improvements as cumulative production grows.

- **Have sunset provisions that limit their duration.**

- **Be restricted to emerging technologies that offer major public benefits not fully valued in market prices, that have steep learning curves, and that have good prospects for market penetration after the subsidies have been phased out.**

To spread and reduce risks, buy-down programmes can be designed to support portfolios of new clean energy technologies.

Competitive market transformation initiatives should be given close attention for two reasons. First, they offer cost-savings potential. Second, ongoing energy market reforms provide an opportunity for introducing policy measures that would make technology buy-down easier. Examples of competitive market transformation initiatives include the U.S. Renewable Portfolio Standard, Germany's former Feedstock Law, and the recently abandoned U.K. Non-Fossil Fuel Obligation (see above). As noted in the next section, focused attention should be given to cost buy-down initiatives in developing countries.

Widespread deployment. Even after successful buy-down, new energy technologies being pursued for sustainable development benefits often face significant institutional barriers to widespread deployment. The removal of such barriers - for example, the sorting out of patent issues, or support for domestic savings institutions - is an important public policy objective.

Many of the market reforms discussed in the section on making markets work better

(removing subsidies, internalising externalities) will facilitate widespread deployment of some new clean energy technologies. Such reforms will be especially helpful in accelerating the deployment of the new cogeneration and polygeneration options discussed in chapter 8. In addition, green energy labelling and energy marketing are made possible by market reforms that enable consumers to choose their energy suppliers.[9]

One important set of policy issues relates to scale. Some promising new clean energy technologies are small-scale and modular, offering attractive economics through their potential for low cost through mass production and their potential for deployment near users, where market values are high. But deployment of such technologies, which includes both efficient end-use technologies and small-scale production technologies, faces barriers at both the consumer and producer levels.

As discussed in the section on raising energy efficiency, users of small-scale technologies often lack information on product availability, costs, and benefits and face barriers to financing. For providers of energy services from small-scale technologies, a major challenge is overcoming the high transaction costs that often characterise small-scale systems. Policies to encourage economies of scope and scale would be helpful in this regard.

Economies of scale might be exploited through policies that facilitate the development of industries that are able to exploit commercially - through the introduction of innovative products and services - efficiency standards, renewables portfolio standards, 'green certificate' markets, energy labelling of mass-produced products, and cooperative procurement. Energy service companies that provide consumers with a broad range of energy services - whether on their own or through franchises or concessions - may also emerge (see also chapter 10). Franchises and concessions

should be issued competitively, under contracts that require winners to meet strict societal obligations (often, the obligation to serve all consumers in the franchise or concession territory) in exchange for monopoly rights. A long history of cooperative ventures to promote rural electrification (for example, in Argentina, Canada, and Europe) offers a model for supporting the diffusion of small-scale technology (see the section above on widening access). Two off-grid solar photovoltaic joint ventures in South Africa, between Eskom and Shell and British Petroleum/Amoco, are other successful models.

A note of caution about new technologies and innovation policies. Societies hope and expect that new technologies will liberate humans and enhance the environment - and this is often the case. But not all technologies provide the benefits sought or intended. Technology can be a source of environmental damage as well as a remedy (Grbler, 1998). Perverse consequences may follow from what were intended as benign interventions (Jewkes, Sawers, and Stillerman, 1958). Experience highlights the virtues of caution, the need for open and multiple processes, and the desirability of taking nothing for granted.

In pursuing new technologies, the risks and liabilities of potential negative outcomes should be addressed fundamentally and holistically, so that actions relating to better understanding and avoiding or mitigating potential adverse side effects are made an integral part of the innovative process. A key element of a strategy to minimise the risks of adverse unforeseen consequences should be to take a portfolio approach to technology development (that is, 'don't put all your eggs in one basket'). The preceding chapters show the rich diversity of technological opportunities for pursuing sustainable development goals.

Moreover, long-term research on promising technologies is usually cheap insurance in

pursuing sustainable development (Schock and others, 1999). And because many of the more promising technologies for achieving sustainable development objectives are small-scale and modular (fuel cells, efficient building and automobile design, photovoltaic systems), it should be feasible to construct commercial technology portfolios that are not too costly. Such considerations also underscore the importance of energy strategies that emphasise more efficient use of energy. With lower energy demands, society gains greater flexibility in choosing among advanced energy supply options and can avoid major commitments to those that appear to pose greater risks.

Even where there is clear evidence that public spending on energy R&D has fallen or remained static, this may not indicate a need for increased public spending. It may reflect shifting priorities or the need for a change in priorities - away from unrewarding programmes or those insufficiently geared to sustainable development. Public policies, like markets, should be in a continuous process of evaluation and change with the intention of learning from others and striving to do better: employing a pluralistic approach, not seeking monolithic social ends (Popper, 1961 [addenda to 1945]).

Still, the considerations in this section suggest that it may be desirable to seek new public-private partnerships for accelerating sustainable energy technology innovation in the 21st century. In partnership with the private sector, governments may seek to define broad objectives and timetables for appropriate technological innovation consistent with sustainable development, and back up these objectives with appropriate incentives. The private sector would necessarily play the main role in exploring the main technological choices and making the investments needed to meet these objectives. The option of carrying out demonstration projects under international auspices should also be explored, along with innovative ways of financing such projects.

Encouraging technological innovation in developing countries

Instead of following the example of today's industrialised countries, developing countries have the opportunity to leapfrog directly to modern, cleaner, and more energy-efficient alternatives. Some developing countries are well-positioned - from the standpoint of their rapidly growing energy demands, nascent infrastructure, and natural resource endowments - to reap the benefits of technological leapfrogging. In some cases developing countries may even be able to adopt emerging new technologies with near-zero emissions - resolving the seemingly inherent conflict between environmental protection and economic development.

There are many developing country examples of technological leapfrogging. One of the most familiar is the widespread adoption of cellular telephones, which has eliminated the need for overhead telephone line infrastructure as a precondition for the diffusion of telephone technology. There are some notable examples of developing countries being the first to adopt new technologies, including energy-related technologies. The following advanced iron-making technologies are among them: direct reduction using natural gas (Mexico), modern charcoal-based iron-making (Brazil), and first-generation smelt reduction technology (South Africa). In addition, China is a world leader in biogas technology. And Brazil led the world in the production and use of biomass-derived ethanol as a transport fuel, although this initiative has received less public support in recent years.

Opportunities for technological leadership

Leapfrogging over some of the historical steps in the technological development of today's industrialised countries is a widely accepted principle. But conventional wisdom cautions against developing countries taking the lead in commercialising

technologies not widely used elsewhere. Because developing countries face so many pressing needs (see chapter 2), the argument goes, they cannot afford to take the many risks associated with technological innovation. There is reason to modify this view in some situations.

First, developing countries in general - and rapidly industrialising countries (Brazil, China, India, Indonesia, South Africa) in particular - are becoming favourable theatres for innovation. Most developing countries are experiencing rapid growth in the demand for energy services, a necessary condition for successful technological change. Moreover, many rapidly industrialising countries have large internal markets and are moving towards the development of strong domestic capital markets and market reforms, including energy market reforms, that will provide more favourable investment climates. In many cases these countries also have a large cadre of suitably trained engineers and others who can contribute to technological advance.

Second, developing countries need new technologies different from those of industrialised countries. For example, most developing countries are in the early stages of infrastructure development. They have enormous demands for basic materials and need innovative technologies that will facilitate infrastructure development. In industrialised countries, by contrast, the demand for basic materials is reaching the saturation point, and there is little need for fundamentally new technologies for basic materials processing.

Third, early deployment of advanced energy generation and use technologies that are inherently low polluting offers advantages in coping with the growing environmental problems that are rapidly becoming major concerns in developing countries, and where end-of-pipe solutions are inherently costly and likely to become more burden-some as regulations tighten. This is an important consideration for most developing

countries, where regulations for environmental management are at a very early stage.

Users of small-scale technologies often lack information on product availability, costs, and benefits and face barriers to financing.

Fourth, local manufacturing could lead to larger domestic markets and opportunities for export growth. Lower wage costs, at least in the early stages of economic development, could contribute to cost competitiveness. All these factors suggest that new sustainable energy technologies could reach competitive levels if substantial early deployment opportunities are pursued in developing countries.

In addition, substantial benefits may arise from combining local customs and practices with new technologies, processes, and materials. Vernacular architecture, long suited to local climatic conditions and culture, may be intrinsically superior to imported designs and materials, yet open to benefits from better processes and materials. Cooking and space heating devices may be similarly open to local reconfiguration.

Supporting demonstration and diffusion

Beyond the widely applicable remarks already offered on policies supportive of energy innovation (see the section on the rationale for public policy support), a few additional considerations apply specifically to demonstration and cost buy-down projects in developing countries. Demonstration projects will be needed in many developing countries because technologies developed elsewhere should be tailored to host country needs. In addition, some of the needed technologies - such as biogas- and

biomass-derived gaseous and liquid cooking fuels and small-scale biomass power generating technologies (see chapter 10) - are unlikely to be developed and demonstrated elsewhere. Yet financing such projects in developing countries is difficult, not only because of the high costs and technological risks involved, but also because it is difficult to get support from industrialised country governments or international agencies.

Focused attention should also be given to possibilities for technology cost buy-down projects in developing countries. Otherwise, large volumes of new equipment based on old, polluting technologies are likely to be installed in these countries and locked in place for decades to come. Moreover, the rapid growth in energy demand in these countries offers an opportunity to buy down technology costs more quickly than in the relatively slow-growing markets of industrialised countries. Broad-based financial support and risk-sharing strategies are likely to be key for both demonstration and cost buy-down projects.

In the absence of proactive measures, barriers to international trade may have to be resorted to, in order to impede imports of less efficient and dirtier technologies, and to provide preferences for more efficient and cleaner technologies. Environmental treaties using trade measures date back to 1881, when steps were taken to prevent the international transfer of phylloxera in vines. Recent examples include CITES, which constrains trade in listed species and products; the UN agreement on conserving and managing straddling fish stocks and highly migratory fish stocks; and the Montreal Protocol, which requires signatories to ban imports of ozone-depleting substances from non-signatories not in compliance with the protocol. The World Bank has outlined the reasons multilateral trade measures, but not unilateral ones, may be justified to help tackle global environmental problems - provided they can be made effective (World Bank, 1999d). And in June 1997 the UN General Assembly adopted

proposals to make trade and the environment mutually supportive. If trade measures were used wisely and well in international environmental agreements, they could facilitate technological leapfrogging.

International industrial collaboration

Economic globalisation and ongoing market and institutional reforms are attracting more private capital to developing countries, as reflected in the sharp increase in private investment in these countries (especially net foreign direct investment). In contrast, the drop in official development assistance from OECD countries suggests that the adverse environmental consequences accompanying industrialisation in developing countries are unlikely to be corrected by aid unless there is a huge turnaround from the declines of the 1990s. This implies that the private sector should be looked to in order to fill the vacuum. The fact that legal rights to and experience with most advanced and new technologies exist in the private domain needs to be acknowledged and suitably compensated for (possibly by industrialised governments in support of technology transfer) if the vacuum is to be filled. Making industrialisation an instrument for sustainable development could prove an important means of addressing these problems (Wallace, 1995).

International industrial collaboration could provide a means to exploit the potential cost advantages of early deployment of state-of-the-art sustainable energy technologies in some rapidly industrialising countries. Such collaboration could also foster the development of such technologies to the point that developing countries become world leaders and even exporters of such technologies. Among alternative approaches to industrial collaboration, the international joint venture is especially promising for technology transfer (STAP and GEF, 1996).

In principle, private sector-led technology transfer holds considerable appeal. But some developing country policy-makers believe that payments for technology are beyond their means and that international technology transfer contributes little to technological development in the recipient economy. Through empirical research on factors affecting energy-saving technical changes in Thailand's energy-intensive industrial firms, Chantramonklasri (1990) has shown that such problems can be reduced if measures are taken to promote "active technological behaviour" by technology-importing firms. He points out that effective technological development requires complementing the acquisition of capital goods, services, and operational know-how with the acquisition of system-related knowledge.

Among alternative approaches to industrial collaboration, the international joint venture is especially promising for technology transfer.

This includes the basic technological principles involved, the various technical and managerial skills and experience needed to use the acquired system effectively, and initiatives to improve the system incrementally in light of local conditions and needs.

The research shows that the greater is the stock of technological capabilities within and around technology-importing firms, the greater are the increments to that stock that can be acquired in industrial collaborations. Chantramonklasri finds that with active intervention and interaction, a virtuous circle can lead to gains in technological capacity and industrial productivity. Firms that fail to take actions that enable them to enter the virtuous circle will be left in a vicious circle of technological dependence and

stagnation.

Towards a supportive policy framework

As discussed, developing and transition economies can increase economic efficiency by introducing reforms that price energy rationally, promote competition in energy markets, and strengthen domestic capital markets. Such market reforms also facilitate energy technology transfer and energy technology innovation generally. Along with relatively rapid growth in the demand for energy services, these reforms can create strong markets in these countries and encourage the provision of energy technologies that are well suited to domestic needs.

The market reform process provides a window of opportunity for simultaneously introducing reforms that facilitate the introduction of innovative sustainable energy technologies. The process may be enhanced by governments setting goals that define the performance characteristics of qualifying sustainable energy technologies (for example, by specifying efficiency and air pollution emission characteristics). The setting of these goals can be complemented by credible regulatory or other policy mechanisms that favour sustainable energy technologies in energy market choices.

Policy-makers should also consider introducing institutional reforms that facilitate the formation of international joint ventures and other international collaborative efforts to encourage sustainable energy technology transfer and innovation. Where such reforms are conducive to greater political stability, more straightforward transactions, and fewer arbitrary interventions, they are likely to prove especially supportive of technological innovation and diffusion. Bilateral and multilateral financing and assistance agencies could usefully be encouraged to be more open to supporting energy technology innovation that is consistent with sustainable development goals.

Capacity and institution building

Capacity and institution building are needed if sustainable energy technologies are to fulfil their potential in contributing to the sustainable energy development of developing and many transition economies. Programmes should build on the experience of the World Bank and UNDP (such as UNDP's Capacity 21 Programme, cited above) and on the experience gained in numerous developing countries (Farinelli, 1999).

One priority is training aimed at providing expertise for staffing companies that will produce, market, install, and maintain sustainable energy technologies. This need has been underscored by evidence that higher technical and managerial skills among staff of host country partners in international industrial collaborations improve prospects for successful technology transfer and innovation (Chantramonklasri, 1990). Technological capability can also be raised by establishing regional institutes that provide training in the basic skills of technology management. Such institutes are likely to be more effective if they enjoy close links to energy technology user groups.

Public agencies and private research institutes in industrialised countries could also help build capacity for sustainable energy development in developing and some transition economies, by helping to form and staff parallel institutions in these countries to assist local policy development and technology assessment. Regional and national programmes and centres for renewable energy and energy efficiency promotion in Brazil, China, India, and Eastern Europe could serve as models. Such agencies and research institutes can help provide independent assessments of alternative technology and policy choices, and can explore strategies for overcoming barriers inhibiting large-scale implementation of sustainable energy technologies.

There is also scope for coordinated initiatives between specialised consultancies, companies, and local communities.[10] These ideas do not imply, however, that specialists in industrialised countries have achieved the desired results of sustainable energy development, and that they can now apply their efforts elsewhere. This is not the case, and it would be condescending even if it were. The challenges remain global.

Moving towards more effective cooperation

In recent decades there has emerged a growing sense that many of the issues facing today's world cross national boundaries - and that national policies and measures are insufficient to address them. This is particularly the case for resource exploitation, support for the needy, and environmental issues with cross-boundary impacts. A view is emerging that internationally harmonised measures are becoming increasingly necessary to improve performance standards, reduce adverse environmental impacts of human activities, and accelerate change in the directions widely desired.

To do so successfully, however, requires careful evaluation, adequate funding, and appropriate conditionality on spending to ensure that it conforms to its intended purpose. As set out in numerous UN documents, and agreed to by all the parties to them, industrialised countries have undertaken to take the lead in this endeavour, not least by supporting the transfer of technology, finance, and know-how to developing and transition economies. Although international cooperation in these matters is still in its infancy, many consider the pace of progress unsatisfactorily slow relative to the scale and nature of the problems facing our world.

In June 1997 the UN General Assembly Special Session noted the increasing need for better coordination at the international level as well as for continued and more concerted efforts to enhance collaboration among the secretariats of international

organisations in the UN system and beyond (clause 117; see Osborn and Bigg, 1998, p. 185). Along those lines, the UN Commission for Sustainable Development was asked to establish closer interaction with a range of international institutions and to strengthen its interaction with and encourage inputs from a range of social actors (clause 133; Osborn and Bigg, 1998, p. 189).

More recently, the roles of the International Monetary Fund and the World Bank have come under scrutiny, particularly in the contexts of whether their resources are sufficiently targeted on improving the development performance of the poorest countries and on the criterion of sustainable development. Where existing jurisdictions are not sufficiently broad or institutions do not move quickly and effectively enough to meet policy goals or allay public concerns, consideration should be given to institutional reform or the creation of new institutions.

Issues that fall into multiple jurisdictions require coordinated international action. These include international trade disputes, transnational efficiency and performance standards for equipment and appliances, international aviation and marine bunkers, and transit corridors for energy transport (pipelines, tankers, and grids).

The World Trade Organization (WTO), created in 1995 to succeed the General Agreement on Tariffs and Trade (GATT) after completion of the Uruguay Round of international trade negotiations, has a mandate to expand multilateral trade. It operates by policing the multilateral trade system and by seeking to resolve trade disputes through ‘independent’ dispute panels. Widely regarded as a vehicle for globalisation, its activities have been criticised by special interest groups who see globalisation as a threat - to trade unions, environmental protection, and local cultural values and customs.

The WTO meeting in Seattle, Washington, in December 1999, intended to start a new round of trade liberalisation, turned into a "fiasco" according to *The Economist* (4 December 1999). The same magazine recognised the following week that this was "only the latest and most visible in a string of recent NGO [non-governmental organisation] victories". The official outcome of Seattle was that the effort to start a new round of trade negotiations was "suspended". Criticism continues of what are claimed to be the WTO's unwieldy structure, arcane procedures, and numerous festering disputes.

Yet free international trade is of great importance to developing countries - by 1999, 134 countries had joined the WTO (World Bank, 1999d) - and to the welfare of poor people. There is a vast literature on the links between trade and increased incomes for the poor as well as the relatively rich. WTO critics are particularly vocal on the need to link free international trade with new initiatives on employment standards (which risk undermining the competitiveness of developing countries and protecting jobs in industrialised countries) and the environment. They are also usually highly critical of the role of major companies involved in international business.

The International Labour Organization plays a key role in employment conditions. There are various environmental initiatives under UN auspices (through the United Nations Environment Programme, United Nations Framework Convention on Climate Change, and so on). The United Nations Conference on Trade and Development (UNCTAD) has been concerned since 1964 with improving the prospects for developing countries' trade. This could be accomplished by better coordinating international action on multilateral trade, including a closer link to the needs of sustainable development. The WTO could play a significant role in promoting sustainable energy development in general, and technology leapfrogging in particular, by developing supportive multilateral trade measures. This discussion is in line with

the need perceived by the UN General Assembly Special Session in June 1997 to make trade and the environment mutually supportive.

International initiatives on international aviation and marine bunkers are proceeding slowly. In both cases users and beneficiaries are not paying the full costs of operations. In international aviation, costs should capture the impacts of flight on the lower stratosphere and upper atmosphere, of emissions and noise at lower levels, and of infrastructure requirements on the ground (Penner and others, 1999). In international maritime movements, the full effects of emissions and spills should be captured in costs and the onus for reductions and removal should be placed firmly on the operators. Increasingly stringent standards should be imposed, especially for sea-going vessels in which multihull construction and high maintenance standards may not be readily detectable.

Under the aegis of the UN Framework Convention on Climate Change, the International Civil Aviation Organization and the International Maritime Organization have been asked to report on greenhouse gas emissions associated with international aviation and marine bunkers. The environmental impacts of these emissions go beyond global climate change, however.

Cooperative efforts to ensure supply security

Supply security is a concern related to availability, the functioning of markets, and the need for international cooperation. A priority issue for national and international policy in 1971-85 (especially during the crises of 1973-74 and 1978-80), it has slipped down the list of priorities. As discussed in chapters 4 and 5, the world has huge geological resources of fossil fuels, along with considerable potential for energy from non-fossil fuels. It is usually in the interest of producers to keep supplies flowing

smoothly. A common view is that there will be ample oil and natural gas available, that it will be supplied at low prices, and that if financial flows are inadequate, it will mainly be exporters of oil and natural gas who suffer. This perception is applicable at least to the foreseeable future - the first 20 years of this century.

An alternative view should not be overlooked, however. The number of people dependent on imported oil and natural gas is likely to more than double by 2020 from the nearly 3 billion in 1990. Political unrest, economic frustration, or simply misjudgement about the potential gains from supply disruption could increase over the period. Despite the physical availability of energy sources, precautionary strategies to maintain supply security continue to have merit (see chapter 4; IEA, 1998; EC, 1999). These include:

- **Encouraging open international trade systems.**

- **Maintaining harmonious international diplomacy.**

- **Considering different allocations of tax revenues between upstream and downstream governments (along the lines of 'compensation' for fossil fuel producers and exporters as indicated in article 4.8 (h) of the UN Framework Convention on Climate Change).**

- **Diversifying supply sources (widening the geographic range of suppliers and maintaining adequate storage facilities and inventories of oil and natural gas).**

- **Expanding indigenous supplies of non-fossil fuels, provided there are no severely adverse consequences.**

In the meantime, fluctuating OPEC production levels may cause large price

fluctuations - as with the tripling of crude oil prices in 1999. Market responses have included rising prices of gasoline and of oil products for heating. By March 2000 gasoline prices at the pump had risen above $2 a gallon in many parts of the United States, once again raising questions about 'gas guzzling' vehicles and encouraging the use of public transport. This experience has again demonstrated the potential value of market prices in the promotion of sustainable development.

The Energy Charter Treaty is a potentially useful example of broad international action that encourages its signatories to afford comparable treatment of energy markets, with special protocols being negotiated on energy transit, energy efficiency, and other matters(see also chapter 4). Originally put forward in 1990 as the European Energy Charter, the Energy Charter Treaty was signed in 1994 by some 50 countries, including most OECD countries, all the republics of the former Soviet Union, and the countries of Central and Eastern Europe.

Despite the charter's purpose of facilitating energy trade and investment between the signatory countries, and general recognition of the need for this, the charter has a long way to go before it becomes meaningful in practical terms. The reasons partly lie in the legal and administrative weaknesses and complexities in most transition economies. Moreover, the charter imposes no enforceable obligations on its signatories. Nevertheless, such an approach could in principle be used more broadly to address the significant shift needed to achieve sustainable energy.

A number of regional unions and associations could promote sustainable energy development. More than 80 regional trading arrangements came into force between 1990 and 1998 (World Bank, 1999d). The Mercosur customs union created by Argentina, Brazil, Paraguay, and Uruguay in 1991 (the final protocol was signed in 1994) is one example, with an emphasis on regional cooperation and the abolition of

tariffs. Other organisations in other regions (including several in the Mediterranean Basin) could perform a similar role. Especially in Africa, there is a perceived need for progress on this front. One goal of such regional arrangements could be to promote cross-border interconnections for electricity distribution and gas pipeline networks, to widen access to these fuels.

International cooperation on climate change

The challenge of sustainable development presents significant opportunities for international cooperation. The 1992 Earth Summit was a particular landmark. Tangible outcomes from it include the Rio Declaration, Agenda 21, and international conventions on climate change, biodiversity, and desertification.

The most detailed convention framework is the UN Framework Convention on Climate Change (box 12.6). The Kyoto Protocol is a potentially useful further development - if industrialised countries take effective action to curb their greenhouse gas emissions and supplemental action is taken to implement the Kyoto mechanisms. But progress in implementing the provisions of the Convention on Climate Change has been slower than the threat and likely impacts of global climate change suggest are desirable. Agreement on many issues is proving elusive, including realistic emission targets, speedy and effective introduction of new mechanisms, emphasis on the priority of domestic action by all industrialised country parties, and genuine acceptance of legally binding agreements. Yet all these elements seem to have been agreed to in principle by the parties to the convention.

BOX 12.6. THE MONTREAL PROTOCOL AND THE UN FRAMEWORK CONVENTION ON CLIMATE CHANGE: CONTRASTING EXAMPLES OF INTERNATIONAL COOPERATION

The 1987 Montreal Protocol (and subsequent amendments and tightening) - which curbs the production and use of stratospheric ozone-depleting substances - is the most successful recent initiative for international cooperation. Except for a few outstanding issues (such as the continued production and smuggling of these substances), this initiative was agreed to with unprecedented speed and has proven increasingly effective.

The speed and outcome of the UN Framework Convention on Climate Change and its subsequent agreements are far less certain, even though the framework is solid. As a way of drawing lessons from the success of the Montreal Protocol, it may be useful to consider some of the factors that contributed to it, relative to similar elements in the effort on climate change.

In terms of the pace of international action on climate change, the first point is key. Many public statements are predicated on the assumption that climate change is problematic only over the long term. They tend to under-estimate how much climate change is believed to have already occurred (even taking into account natural variability) and how long it will take for atmospheric concentrations of greenhouse gases to cease rising.

According to scientists and informed commentators, the situation calls for greater urgency. Mean surface temperature levels have risen by about 0.8 degrees Celsius since the 1890s. The 20th century warming (in 1910-45 and 1976-99) was the fastest in more than 800 years. The 1976-99 warming converts to a centennial rate of change of almost 2 degrees Celsius.

Perhaps of greater significance, the atmospheric concentration of carbon dioxide (currently about 368 parts per million by volume, or ppmv) is considerably higher than at any time in at least 400,000 years - and perhaps for 15 million years. It is already more than 30 percent higher than the pre-industrial level (280 ppmv) of the early 1800s. Given what is firmly known about the science of the greenhouse effect, this is disturbing. The most optimistic and environmentally driven scenarios suggest atmospheric carbon dioxide concentrations peaking around 2060 at about 430 ppmv, and falling only slowly over the next 50 years, with global surface temperature rising by about 1.5 degrees Celsius. Even this increase could have significant local and regional impacts.

But there is a real risk of much greater temperature increases, with severe consequences, if atmospheric concentrations of the key green-house gases continue on the upward path of recent decades. For 10 years the Intergovernmental Panel on Climate Change has maintained its view that global anthropogenic carbon dioxide emissions need to be cut by at least 60 percent from their 1990 level in order to eventually stabilise atmospheric concentrations at their 1990 level of 353 ppmv (Houghton, Jenkins, and Ephraums, 1990).

Montreal Protocol	Convention on Climate Change
A widely acknowledged and immediate (as well as long-term) threat to human well-being, with clear identification of human causation.	Dispute over the scale, urgency, and human causation of climate change - although in principle the convention regards scientific uncertainties as irrelevant to the need for precautionary measures.
A widely available range of alternatives for use in industry (a result of extensive research and development in both industrialised and developing countries).	Alternatives to fossil fuels and clean fossil fuel technologies are still emerging. Their widespread availability and affordability will require further support.
Support from crucial industry players.	Industry has been receiving mixed signals and has sent mixed signals (especially some sections of U.S. industry), and there are many players.
Industrialised countries willing to financially support programmes for reducing ozone-depleting substances in developing countries.	Multilateral and bilateral support for pilot projects, but without crediting and after considerable opposition from many developing countries.

Despite international concern, the UN Framework Convention on Climate Change and its aims, and the Kyoto Protocol and its targets, many industrialised countries continue to increase their greenhouse gas emissions, especially of carbon dioxide (table 12.3). Data for 1999 suggest that carbon dioxide emissions from fossil fuel combustion rose 2 percent in Canada and the United States (though against a backdrop of even faster real GDP growth). The three original OECD Pacific economies (Australia, Japan, and New Zealand) also increased their carbon dioxide emissions by almost 2 percent. By contrast, the 15 members of the European Union saw emissions drop 0.5 percent from 1998. Reductions in China's carbon dioxide emissions from coal burning - which first became apparent in 1997 - were even more marked, dropping by more than 5 percent in 1999. This progress is exceptional, and may not be long-lasting. The policies, measures, and technologies that would permit the lowering of future trajectories of developing country emissions are not being put in place quickly enough.

Once frameworks have been established through intergovernmental negotiation, signature, and ratification, actual progress relies on genuine cooperation. Politics and short-term manoeuvres need to give way to seeking the most cost-effective and technically feasible means of accelerating progress towards the agreed goals. One problem is that commitments entered into by negotiators are not always enacted by lawmakers, which complicates the timely pursuit and achievement of goals relating to sustainable development. For this reason, new mechanisms are needed and should be given practical trial without delay. If such mechanisms prove effective, early movers could be given tangible rewards. Short action plans could accelerate performance. Achievement of commitments could be enhanced by legally binding penalties for non-performance.

Where divisions and delaying tactics exist, the underlying problem of lack of societal commitment, political support, or agreement within the national government may need to be addressed separately. The preferred option in such circumstances is to gain the support of other social actors - from business and industry, local communities and municipal governments, and environmental and other socially concerned non-governmental organisations (NGOs).

The Clean Development Mechanism and Joint Implementation articles (12 and 6, respectively) of the Kyoto Protocol, negotiated in 1997 under the UN Framework Convention on Climate Change, offer potentially important opportunities to increase investments in developing and transition economies, respectively, in sustainable energy. The complex nature of climate change negotiations and the uncertainties surrounding the issue mean that effective introduction of such instruments may not come about for many years(though some people hope that real implementation may follow quickly from the Sixth Conference of the Parties to the Climate Convention, or COP-6, in November 2000). Meanwhile, a growing number of people in the industrialised world's business and industry community have already developed plans to participate in relevant projects drawing on the mechanisms that have been tabled, especially in the Kyoto Protocol, and are experimenting with emissions trading under article 17 of the protocol.

TABLE 12.3. CHANGES IN CARBON DIOXIDE EMISSIONS FROM FOSSIL FUEL USE, 1990-99 (PERCENT)

Area	Change
Canada andthe United States	+12.7
Latin America	+23.3

European Union	+0.8[a]
Central and Eastern Europe/CIS Republics	-35.8
Middle East	+62.7
Africa	+21.9
Asia and the Pacific (excl. Australia, Japan, New Zealand)	+34.8
Total OECD (excl. Hungary, Rep. of Korea, Mexico, Poland)	+10.8
Developing countries	+34.3
World	+7.6

a. If not for major reductions in Germany (-13.5 percent) and the United Kingdom (nearly -8 percent), this figure would be much higher.

Source: Jefferson, 2000.

In 1999 a World Energy Council pilot project (strongly supported by Asea Brown Boveri) identified nearly 400 projects in some 80 countries expected to avert 720 million tonnes of carbon dioxide by 2005. (The project also identified another 91 potential or planned projects that could avert an additional 139 million tonnes of carbon dioxide.) Although many of these projects may not be additional to what might otherwise have occurred, they indicate that a substantial - though insufficient - effort is under way.

For several years, and especially since the Earth Summit, companies and their senior executives associated with the World Business Council for Sustainable Development have been promoting actions and investments consistent with sustainable energy

development, including climate change mitigation, under an eco-efficiency programme. The European Business Council for a Sustainable Energy Future is one of several regional and national business associations that have been promoting sustainable energy development in general and climate change responses in particular. In Latin America the regional chapter of the World Business Council for Sustainable Development has been very active. More recently, the Pew Center on Global Climate Change has brought together major international corporations (Dow, DuPont, British Petroleum/Amoco, Royal Dutch/Shell Group) to take voluntary steps to reduce their greenhouse gas emissions and raise energy efficiency. These endeavours could usefully be extended to smaller companies and to the particular challenges and opportunities facing developing and transition economies.

Intergovernmental and international institutions have made efforts to take forward the mechanisms set down in the Kyoto Protocol. Potentially one of the most significant recent funding initiatives, in terms of possible scale and geographic range, is the World Bank's Prototype Carbon Fund, launched in January 2000. Involving four governments and nine companies (six of them Japanese electric utilities), the fund raises money from both the public and private sectors. (Governments pay $10 million to participate, companies pay $5 million.) The fund will be used to finance projects aimed at reducing greenhouse gas emissions in developing countries. Participating countries will receive emission credits from the World Bank in line with the emission reductions achieved by the projects.

Although some observers have questioned whether the World Bank is the most appropriate body to conduct this task, it does encourage public-private cooperation, relevant projects, early action, and rewards to early movers. Still, it will be important to ensure the commercial viability of projects so that wider and faster diffusion of sustainable energy technologies can be attained, and to gain general agreement on

credits awarded.

Overall, however, more - and more rapid - work is needed to implement cost-effective precautions in line with the UN Framework Convention on Climate Change. Three features of the Programme for the Further Implementation of Agenda 21, adopted by the UN General Assembly Special Session in June 1997, stand out as having met with an inadequate response:

- **International cooperation on implementing chapter 9 of Agenda 21, particularly in technology transfer to and capacity building in developing countries - which are also essential for the effective implementation of the UN Framework Convention on Climate Change (clause 53; see Osborn and Bigg, 1998, p. 161).**

- **Progress by many industrialised countries in meeting their aim to return greenhouse emissions to 1990 levels by 2000 (clause 48; see Osborn and Bigg, 1998, p. 160).**

- **The need to strengthen systematic observational networks to identify the possible onset and distribution of climate change and assess potential impacts, particularly at the regional level (clause 54; see Osborn and Bigg, 1998, p. 161).**

Widening the involvement in sustainable energy development

A critical mass of general public support will be needed for major changes to take place and the pursuit of sustainable development to occur. Here the role of NGOs could prove increasingly influential and beneficial, building on their contributions in

the 1990s (for example, at the Earth Summit and at the series of conferences taking place on climate change). Some observers have expressed concern that rivalry between NGOs (in part to secure public support and attract funding) could be self-defeating. There has also been concern that NGOs may supplant the role of national governments, with negative as well as positive consequences.

NGOs can nevertheless be expected to play an increasingly important role in bringing the issues discussed in this chapter to a wider audience, in mobilising opinion, and in emphasising the importance of bearing in mind local conditions and cultures - in part through their huge network of contacts. Policy development is likely to benefit from bringing better-informed NGOs to the centre of policy formulation and application. For this to succeed, however, national and intergovernmental institutions will have to genuinely interact and consult in a two-way process.

The same is true for other social actors, whether they be local authorities, business and industry, educational institutions, the scientific community, the media, the young and the old, men and women - all with their particular perspectives and needs. In June 1997 the UN General Assembly Special Session recognised the importance of all these groups (for example, in clauses 11 and 28). But both in the programme it adopted for the further implementation of Agenda 21 and in this chapter, two points may stand out above all others. The first is the need to invigorate a genuine new global partnership. The second is the need to provide adequate and predictable financial resources to developing countries, where private capital flows and an environment conducive to their continuation and expansion are of paramount importance if sustainable development is to be achieved.

A critical mass of general public support will be needed for major changes to take place and the pursuit of sustainable development to occur.

Conclusion

In essence, sustainable development means widening the choices available to humans alive today, and to at least the next few generations. A shift in the direction of energy systems and policies along the lines described in this chapter - towards greater emphasis on end-use efficiency, renewable energies, and low-emission technologies - is necessary for achieving that goal. It is impossible to know in advance the precise combination of policies and policy instruments that will work under different conditions, and the costs and benefits of emerging technologies. But the broad strategies put forward here provide an indication of the way forward. There is also a sufficient variety of policies from which to begin to gauge the more likely successes.

The ongoing liberalisation and restructuring of energy markets and sectors offer an important window of opportunity in which to make many of the needed changes. Growing energy demands in the developing world provide further impetus to make changes sooner rather than later. Energy systems generally take decades to change. If we fail to initiate changes now, it will become more difficult and more costly to undertake them at some later date (WEC, 1995; Nakicenovic, Grbler, and McDonald, 1998).

The policies likely to encourage energy systems that will support sustainable development, as discussed in this chapter, are founded on the underlying aim of making markets work better. Additional investments in environmentally friendly technologies will be required, as will encouragement of the innovation and diffusion of

sustainable energy technologies. Successful implementation of these policies requires improving the costing and pricing of energy carriers and services, as well as specific regulations to raise efficiency and reduce pollution, in order to ensure greater and wider public benefits.

Making markets work better

Policies that reduce market distortions (that is, level the playing field) would give sustainable energy - new renewable sources, energy efficiency measures, new technologies with near-zero emissions - a considerably better market position relative to conventional energy sources. Market distortions can be reduced by phasing out permanent direct and indirect subsidies to conventional energies and energy use in all end-use sectors, by including social and environmental costs in prices, and by introducing appropriate regulation, taxes, or financial incentives.

Another way of making markets work better is to complement ongoing market reform with regulations that support sustainable energy. A number of the obstacles to greater energy end-use efficiency are the result of market imperfections or barriers. Options to overcome these barriers include voluntary or mandatory standards for appliances, vehicles, and buildings; labelling schemes to better inform consumers; technical training in new energy efficiency technologies and their maintenance; and credit mechanisms to help consumers meet higher first costs.

Mobilising additional investments in sustainable energy

Incentives may be needed to encourage private companies to invest in sustainable energy or to defray the risks associated with such investments. International funding sources may also need to play a greater role in the least developed countries,

especially those where the overall conditions that attract business are lacking and joint efforts are required to improve those conditions. Supportive financial and credit arrangements (including many microcredit arrangements already in existence) will be needed to introduce commercial energy to those excluded from markets, especially in rural areas.

For decentralised provision of modern energy services, capital costs may best be met from a mix of local equity capital (communal or private) and loans from banks or other conventional credit organisation at commercial rates. There may be a role for industrialised country governments in backing loans with guarantees, on mutually acceptable criteria. Subsidies, with 'sunset' clauses for environmentally sustainable technologies, may help. Above all, a one-stop approach from agencies specialising in the financing of rural electrification and renewable energy schemes would be beneficial - especially in overcoming the barriers associated with current time-consuming and costly procedures. The scale of such arrangements will need to be massively expanded to achieve the required results. The principles of good governance - including stability, probity, and the rule of law - are also significant for the promotion of investment.

Encouraging technological innovation

Currently applied technologies are not adequate to deliver the energy services that will be needed in the 21st century and simultaneously protect human health and environmental stability. Adequate support for a portfolio of promising advanced and new technologies is one way to help ensure that options will be available as the need for them becomes more acute. Direct government support is one option, but the historic record is somewhat discouraging and suggests that support for generic research rather than large-scale commercialisation is likely to be more fruitful. Other

ways to support technological innovation, while still using competition wherever possible to keep down costs, include tax incentives, collaborative R&D ventures, government and industry procurement policies, 'green labelling' schemes, public benefits charges, and market transformation initiatives.

The ongoing liberalisation and restructuring of energy markets and sectors offer an important window of opportunity in which to make many of the needed changes.

Supporting technological leadership and capacity building in developing countries

Because most of the projected growth in energy demand will occur in the developing world, innovation and leadership in energy technologies could be highly profitable for some developing countries in economic, environmental, and human terms. But they will need assistance with technology diffusion (including transfers), financing, and capacity building. Much of this support will need to be led by the private sector, by private-public partnerships, or both.

Consideration could be given on a multilateral basis to providing preferential treatment for international trade in cleaner and more efficient technologies and products, within international trading arrangements that could be adjusted more clearly towards sustainable energy development. Wider use of green labelling schemes and harmonised regulations and standards would help. International industrial collaboration offers a way for the private sector to gain markets while fostering the migration of new technologies to developing countries. Public agencies,

private research institutes, and regional institutes that provide training in technological management are additional possibilities for further technology sharing and capacity building. Coordinated institutional approaches are required for capacity building, effective market functioning, technology diffusion and financing, and successful international initiatives. Community participation can also play an important role in promoting these policies.

Encouraging greater international cooperation

Ongoing globalisation means that ideas, finances, and energy flow from one country to another. In this context, isolated national actions are no longer likely to be the only or the most effective option. Two key areas in which harmonisation could be helpful are environmental taxes and efficiency standards. The need for concerted action on energy is also clear from the major international conventions that emerged from the Earth Summit - particularly the UN Framework Convention on Climate Change. Although the basic principles and many more detailed articles of that convention encourage sustainable energy development, and should provide an excellent framework for future progress, implementation has been slow relative to the urgency of achieving greater sustainability.

The challenge of sustainable energy includes crucial enabling roles for governments, international organisations, multilateral financial institutions, and civil society, including the private sector, NGOs, and individual consumers. Partnerships will be required, based on more integrated and cooperative approaches, and drawing on a range of practical experience. A common denominator across all sectors and regions is setting the right framework conditions and making public institutions work effectively and efficiently with the rest of society and economic actors in reaching beneficial and shared objectives.

Used safely and wisely, energy can make a powerful contribution to sustainable development. Redirecting its power to work towards the overarching goal of sustainability, however, will require major policy changes within an enabling overall framework. Poverty, inequity, inefficiency, unreliable service, immediate environmental priorities, lack of information and basic skills, and absence of needed institutions and resources require that changes be made. Unless truly significant changes begin to take place within the next 20-30 years, many of the opportunities now available will be lost, the possibilities for future generations diminished, and the goal of sustainable development unrealised. The ninth session of the UN Commission for Sustainable Development provides an opening in which to galvanise consensus on the energy and transportation issues discussed in this chapter. The special session of the UN General Assembly in 2002 is a further opportunity to pursue ways in which the broader international policy framework can be more supportive of sustainable energy goals.

Annex. Trends in research and development funding

It is widely held that R&D expenditures on sustainable energy technologies are too low and falling. This annex examines R&D trends in more detail. As discussed in box A12.1, however, because of the way the data are collected, categorised, and compared, the accuracy of the figures cited here and elsewhere is difficult to assess.

Private sector spending on energy research and development

Private sector spending on energy R&D, based on U.S. data, is believed to have been low as a share of sales over a long period. In recent years U.S. utilities appear to have invested just 10 percent as much as U.S. industries overall. But whereas most major electric utilities and oil and gas companies in OECD countries spend less than 1

percent of sales on R&D, the main research-oriented firms servicing broader energy technology needs (such as Asea Brown Boveri and Siemens) invest 8-30 times as much. Still, spending on energy R&D generally seems low relative to the 7 percent of GDP represented by retail spending on energy in countries that are members of the International Energy Agency.

On the other hand, in several countries with relatively detailed and reliable data on private sector spending on energy R&D - such as Finland, Germany, and Japan - it is clear that there have been significant overall increases in recent years. Part of the explanation is that during the 1990s these countries saw sharp increases in R&D spending on renewables, energy efficiency, and advanced cleaner fossil fuel technologies. The progress of private sector spending on energy R&D in Japan, as provided in a major report prepared in 2000 (Ito 2000), is distinctly more upbeat than others have reported (Dooley, 1999a). Although private sector spending on energy R&D in Canada has remained flat in real terms since the early 1980s, this masks a decline in fossil fuel R&D on the one hand, and an increase in energy efficiency, fuel cell, climate change technology, and electricity R&D on the other. There is no evidence of a decline in utilities' spending on R&D in Norway and Sweden (Haegermark, 2000). In Germany private sector R&D has assumed an increasing role while government R&D has fallen. In Austria, although there have been considerable variations in recent years, industrial spending on renewable energy - particularly biomass - rose sharply in 1996-98 (Faninger, 2000).

Thus there are strongly contrasting experiences. The reported decline in private sector energy R&D in the United States is seemingly shared by Italy, Spain, and the United Kingdom. There can be no doubt that spending on nuclear R&D collapsed in many countries during the 1990s. In the United Kingdom spending on energy R&D is estimated to have fallen by some 40 percent in the gas and electricity industries

following privatisation, and by 55 percent in the coal and oil sectors. But the position on renewable energy and energy efficiency R&D is not so dismal even in the latter countries. And due to increasing R&D productivity benefits arising from improving information technology, it has been claimed that even where spending has declined, productivity may have increased.

BOX A12.1. INTERPRETING DATA ON RESEARCH AND DEVELOPMENT

There are several reasons for caution when considering the energy R&D data presented in this annex - or almost any such data. First, there is no universally accepted definition of energy R&D (although it should include basic and applied research, feasibility testing, and small-scale deployment). Detailed classifications are rarely provided for data series and are not comparable between series. Even in the United States the only official surveys of private industry spending on energy R&D - the National Science Foundation annual surveys - provides only a "most cursory" definition of energy R&D, and "there is no way of knowing what kinds of energy technologies are being developed by industry through looking at this data set" (Dooley, 1997, appendix I, p. 1). The surveys exclude energy R&D conducted by non-profit organisations (recourse has been made to the Electric Power Research Institute and Gas Research Institute to try to remedy this omission). The situation is even less clear in other OECD countries.

Second, distortions arise because of a failure to use a common currency basis. For example, since market exchange rates rather than purchasing power parities are used, it has been claimed that R&D spending by Japan is inflated relative to that by the United States (Dooley, 2000).

Third, aggregate data often exclude most military-related R&D spending and ancillary benefits (such as the development of jet engines for military purposes and their impact on combined-cycle gas turbines). Thus the data are misleading.

Fourth, comparison of R&D spending over time is complicated by increases in the productivity of R&D spending - due, for example, to the use of better data processing hardware and software.

Two firm conclusions can be drawn from this catalogue of problems. The first is that even official government statistics and international comparisons thereof should be handled with extreme care. The second is that the quality of data needs to be improved to permit sound comparisons over time and among countries and technologies if it is to form a basis for policy.

There is no way of knowing with confidence what level of spending on energy R&D is optimal, or even sufficient for short-term needs. Although R&D spending by the oil sector seems to have been low, this did not prevent major gains in exploration and enhanced recovery - including cost reductions - in recent years. Similarly, low R&D spending by gas and electric utilities does not seem to have blocked a rapid shift to combined-cycle gas turbines for electricity generation. Nevertheless, it is widely believed that long-range R&D spending has fallen as a share of total R&D spending in the energy sector in several countries. This outcome is attributed to the emphasis the private sector places on incremental improvements to existing technologies and products relative to basic research.

Public sector spending on energy research and development

Since the mid-1980s aggregate public support for energy R&D has fallen steadily in OECD countries (table A12.1). About 80 percent of the decline, however, has occurred in the United States. And declining R&D for nuclear technologies are of the same broad order of magnitude - $4 billion.

In other countries, by comparison, the declines have generally been marginal in value terms, though sometimes large in percent-age terms, with nuclear R&D bearing the brunt of the decline. Japan saw a 20 percent increase in overall energy R&D spending between 1980 and the mid-1990s. Although a small fall occurred in total public sector energy R&D spending between 1995 and 1997, the actual falls were confined to nuclear power, coal, and the conservation and storage of electric power - there were rises in all other energy R&D categories. A sharp decline in public sector energy R&D occurred during the 1990s in the United Kingdom, particularly after the Department of Energy was abolished in 1992 and its remaining R&D responsibilities were handed over to the Department of Trade and Industry (which focuses on the commercial deployment of existing technologies). Declines have also occurred in Italy and Spain. In Germany federal spending on energy R&D has fallen somewhat, but inclusion of lander expenditures results in near stability. Stability or expansion of public spending can be observed in Denmark and Finland. In Switzerland, although there was a slight decline in overall government spending on energy R&D between 1994 and 1997, spending on renewable energy R&D remained stable. In Austria government spending on energy R&D rose steadily through the 1990s. Between 1993 and 1998 spending on renewable energy R&D rose 200 percent. Spending on nuclear fusion R&D was, perhaps surprisingly, higher in 1998 than in 1993. Fossil fuels and conservation were the only areas exhibiting a declining trend (Faninger, 2000). However, it should be noted that the United States and Japan are by far the heaviest public sector spenders on energy R&D.

TABLE A12.1. REPORTED RESEARCH AND DEVELOPMENT BUDGETS AND GDP IN IEA COUNTRIES, 1983-97 (BILLIONS OF 1998 U.S. DOLLARS EXCEPT WHERE OTHERWISE INDICATED)

Year	Fossil	Nuclear	Nuclear	Energy	Renewables	Other	Total	GDP

	energy	fission	fusion	conservation					(trillions of 1998 dollars)
							Billions of dollars	Percentage of GDP	
1983	1.61	6.13	1.39	0.82	1.03	1.09	12.07	0.158	7.64
1984	1.52	5.85	1.41	0.73	1.02	1.01	11.53	0.147	7.87
1985	1.49	6.66	1.46	0.75	0.87	1.06	12.28	0.137	8.99
1986	1.49	5.96	1.33	0.64	0.67	0.96	11.05	0.102	10.82
1987	1.33	4.63	1.26	0.67	0.62	1.07	9.58	0.075	12.71
1988	1.44	3.94	1.18	0.56	0.62	1.24	8.98	0.065	13.85
1989	1.30	4.38	1.09	0.49	0.57	1.39	9.21	0.063	14.72
1990	1.74	3.96	1.06	0.54	0.58	1.21	9.09	0.056	16.23
1991	1.48	3.93	0.95	0.62	0.63	1.42	9.04	0.052	17.41
1992	1.02	3.29	0.92	0.59	0.68	1.32	7.82	0.045	17.43
1993	1.04	3.19	1.00	0.69	0.70	1.44	8.06	0.042	19.13
1994	1.06	3.06	0.96	0.96	0.63	1.43	8.09	0.040	20.07
1995	0.90	3.23	0.97	1.05	0.68	1.39	8.22	0.037	22.44
1996	0.84	3.17	0.86	0.98	0.60	1.38	7.83	0.035	22.14
1997	0.69	3.04	0.83	0.94	0.59	1.43	7.52	0.034	21.99

Source: IEA, 1999.

Among member countries of the International Energy Agency, public sector spending on R&D for energy conservation was generally higher in the 1990s than in the 1980s, and public spending on R&D for renewable energy sources remained fairly static in the decade to 1997. It is worth noting that although EU spending on nuclear fission R&D fell by more than 50 percent between 1988 and 1998, spending on energy efficiency and renewables R&D more than doubled between 1993 and 1996 (from less than $100 million a year to more than $200 million), and has been running in excess of $200 million since. Even public spending on R&D for fossil fuels fell sharply only between 1994 and 1997 - a rather short period on which to base a story of general and sustained decline. Public and private R&D spending on coal and natural gas has tended to increase, particularly for clean fuel technologies and carbon sequestration. EU spending on cleaner energy systems (including cleaner fossil fuels) has increased in recent years and is now around $140 million a year.

There is little evidence on energy R&D spending in developing countries, and with two or three exceptions it is likely that spending has been modest. One exception is South Africa, where energy R&D spending by the Department of Minerals and Energy fell during the 1990s (Cooper, 2000).

Notes

1. Renewable technologies, in the context of this chapter, include modern bio-energy, small hydropower and solar, wind, and geothermal technologies. They exclude large hydropower and estuarine barrage. Large-scale biomass productivity, however, has the potential to undermine biodiversity as well as generate serious adverse visual impacts.

2. The Brundtland Comission is formally known as the World Commission on Environment and Development; see WCED (1987).

3. Abatement of carbon dioxide in specific projects - such as the separation and injection of emissions from Norway's offshore Sleipner Field - has resulted from a $50 a tonne carbon tax levied by the Norwegian government on offshore carbon dioxide emissions. Another project indicates carbon dioxide abatement costs of $28-52 per tonne of carbon (Barland, 1999).

4. Revenue-neutral taxes are new taxes that result in a corresponding reduction of other taxes. While overall government revenues do not increase, the change in the tax regime might have other societal effects.

5. According to World Bank estimates, domestic savings ratios in developing countries often exceed 20 percent of GDP.

6. Examples include advanced oil and gas recovery, combined cycle gas turbine innovations, and integrated gasifier combined cycles. Among new renewable technologies, windpower is already economically competitive in many wind-rich regions; photovoltaic technologies are competitive in applications remote from utility grids and are on the verge of becoming competitive at retail price levels in grid-connected, building-integrated applications; low-polluting internal combustion engine/battery-powered hybrid cars that are twice as fuel-efficient as conventional cars have recently become available; fuel cell cars are being developed that would be three times as fuel-efficient as today's cars; and information technologies are being exploited to improve many energy-producing and energy-consuming technologies.

7. Comparing R&D data from various sources is complicated by the fact that there is

no universally accepted definition of energy R&D. Because of other distortions, described more fully in the annex, even official government statistics and international comparisons must be analysed carefully.

8. Many U.S. commentators point to the failure of synfuel projects, which were predicated on high energy prices continuing through the 1980s. Few specialists took a contrary view, and the best-known exception had been overly confident in the 1970s that OPEC and consumer interests would fail to keep up crude oil prices (Adelman, 1972 and 1995). These stances were never wholly accepted in Europe, where sharp oil price rises in the late 1970s were anticipated by 1976 - along with the assumption that relapse would follow thereafter (Jefferson, 1983).

9. A shortcoming of relying on green pricing to facilitate widespread deployment of clean energy technologies is that there may be a free-rider problem: those who are unwilling to pay more for green energy enjoy the environmental benefits that come from green energy purchases by those who are willing to pay more (Rader and Norgaard, 1996). One way to avoid this is to give a tax deduction on existing carbon dioxide or other energy taxes, as in the Netherlands.

10. A number of international frameworks can be drawn on to support this approach, such as the International Standards Organization (ISO) 14001 introduced in 1996 and for which the 1992 Earth Summit provided the impetus, the Eco-Management and Audit Scheme introduced by the EU Commission in 1995, and the Global Reporting Initiative now under development.

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