part I

energy and major global issues

an introduction to energy

CHAPTER 1

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> The production and use of energy should not endanger the quality of life of current and future generations and should not exceed the carrying capacity of ecosystems.

Life is but a continuous process of energy conversion and transformation. The accomplishments of civilisation have largely been achieved through the increasingly efficient and extensive harnessing of various forms of energy to extend human capabilities and ingenuity. Energy is similarly indispensable for continued human development and economic growth. Providing adequate, affordable energy is essential for eradicating poverty, improving human welfare, and raising living standards world-wide. And without economic growth, it will be difficult to address environmental challenges, especially those associated with poverty.

But energy production, conversion, and use always generate undesirable by-products and emissions—at a minimum in the form of dissipated heat. Energy cannot be created or destroyed, but it can be converted from one form to another. The same amount of energy entering a conversion process, say, natural gas in a home furnace, also leaves the device—some 80–90 percent as desirable space heat or warm water, the rest as waste heat, most through the smokestack. Although it is common to discuss energy consumption, energy is actually transformed rather than consumed. What is consumed is the ability of oil, gas, coal, biomass, or wind to produce useful work. Among fossil fuels the chemical composition of the original fuel changes, resulting in by-products of combustion, or emissions.

This chapter provides a brief introduction to energy's importance for human life and economic functioning, and paints a broad picture of the current energy scene. (More extensive data on energy trends appear in the annexes to this report.) Chapters 2, 3, and 4 examine in greater detail the links between energy and important global challenges, including social issues, health and the environment, and energy security. Chapter 11 analyses prospects for achieving widespread and sustainable prosperity and for reconciling high levels of energy services with environmental protection.

What is sustainable energy development?

In its 1987 report, *Our Common Future,* the World Commission on Environment and Development defines sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 8). The report further describes sustainable development "as a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potentials to meet human needs and aspirations" (p. 46). In its broadest sense, the report notes, "the strategy for sustainable development aims to promote harmony among human beings and between humanity and nature" (p. 65).

The relationship between energy production and use and sustainable development has two important features. One is the importance of adequate energy services for satisfying basic human needs, improving social welfare, and achieving economic development—in short, energy as a source of prosperity. The other is that the production and use of energy should not endanger the quality of life of current and future generations and should not exceed the carrying capacity of ecosystems.

Throughout the 20th century, the ready availability of commercial energy fuelled global economic development. But much of the developing world continues to rely on non-commercial energy sources, mainly fuelwood, and has limited access to modern energy such as electricity and liquid fuels. Lack of capital and technological capacity hinders the development of adequate supplies, with deleterious effects on economic and social development.

Because they affect affordability and economic competitiveness, energy prices need to be taken into account when analysing options for sustainable energy development. Moreover, energy supplies should be secure and reliable. For that reason, attention should be given to:

- The dependence on energy supplies from politically unstable regions or unevenly distributed locations.
- The possible disruption of energy supplies due to severe accidents.
- The sociocultural environment in which energy systems operate.
- The eventual exhaustion of finite energy resources such as coal, crude oil, natural gas, and uranium, for which alternative options must be developed.

Finally, the development and introduction of sustainable energy technology must occur in a socially acceptable manner, with a broad range of citizens participating in decision-making.

No energy production or conversion technology is without risk or waste. Somewhere along all energy chains—from the extraction of resources to the provision of energy services—pollutants are produced, emitted, or disposed of, often with severe impacts on human health and the environment. The combustion of fossil fuels is responsible for most urban air pollution, regional acidification, and risks of human-induced climate change. The use of nuclear power has created a number of concerns about the safety of nuclear installations, the storage and disposal of high-level radioactive waste, and the proliferation of nuclear weapons. The manufacturing of photovoltaic panels generates toxic waste, and in some developing countries the use of biomass contributes to desertification and biodiversity losses.

As noted, to be considered sustainable, energy systems must not overload the carrying capacity of ecosystems. Nor should the use of finite resources compromise the ability of future generations to meet their energy service requirements. Efficient use of resources, clean conversion processes, and the timely development of inexhaustible supply options—such as renewable forms or nuclear energy based on breeding or fusion—are therefore the principal strategies for sustainable energy development.

Evolution of the energy system

From the perspective of society, energy is not an end in itself. The energy system is designed to meet demands for a variety of services such as cooking, illumination, comfortable indoor climate, refrigerated storage, transportation, information, and consumer goods. People are interested not in energy, but in energy services.

> Technology is a critical link between the supply of energy services and access, affordability, and environmental compatibility.

An energy system comprises an energy supply sector and the end-use technology needed to provide energy services (see figure 1 the overview and figure 6.1). The energy supply sector involves complex processes for extracting energy resources (such as coal or oil), for converting these into more desirable and suitable forms of energy (such as electricity or gasoline), and for delivering energy to places where demand exists. The end-use part of the system transforms this energy into energy services (such as illumination or mobility).

Energy services are the result of a combination of technology, infrastructure (capital), labour (know-how), materials, and energy carriers. All these inputs carry a price and, within each category, are partly substitutable for one another. From the perspective of consumers, the important issues are the economic value or utility derived from the services. The energy carrier and the source of that carrier often matter little. Consumers are generally unaware of the upstream activities of the energy system. The energy system is service driven (from the bottom up), whereas energy flows are driven by resource availability and conversion processes (from the top down). Energy flows and driving forces interact intimately (see below). Thus the energy sector should never be analysed in isolation. It is not sufficient to consider only how energy is supplied; the analysis must also include how and for what purposes energy is used.

Modern energy systems rely on manufactured or processed fuels and sophisticated conversion equipment. Traditional energy usually means unprocessed fuels close to their primary form and low-technology conversion devices (or no technology). Low-technology energy conversion usually implies low efficiency and high pollution. Thus technology is a critical link between the supply of energy services and access, affordability, and environmental compatibility. Technology is more than a power plant, an automobile, or a refrigerator. It includes infrastructure such as buildings, settlement patterns, road and transportation systems, and industrial plants and equipment. It also includes social and cultural preferences as well as laws and regulations that reflect the compatibility of technology options with social preferences and capabilities and cultural backgrounds.

The overall efficiency of an energy system depends on individual process efficiencies, the structure of energy supply and conversion, and energy end-use patterns. It is the result of compounding the efficiencies of the entire chain of energy supply, conversion, distribution, and end-use processes. The weakest link in the analysis of the efficiency of various energy chains is the determination of energy services and their quantification, mostly due to a lack of data on end-use devices and actual patterns of their use.

In 1997 the global efficiency of converting primary energy (including non-commercial energy) to final energy, including electricity, was about 70 percent (279 exajoules over 399 exajoules). The efficiency of converting final energy to useful energy is lower, with an estimated global average of 40 percent (Nakićenović and others, 1990; Gilli, Nakićenović, and Kurz, 1995). The resulting average global efficiency of converting primary to useful energy is the product of these two efficiencies, or 28 percent. Because detailed statistics do not exist for most energy services and many rough estimates enter the efficiency calculations, the overall efficiency reported in the literature spans a wide range, from 15 to 30 percent (Olivier and Miall, 1983; Ayres, 1989; Wall, 1990; Nakićenović and others, 1990; Schaeffer and Wirtshafter, 1992; and Wall, Scuibba, and Naso, 1994).

Specific energy services are supplied by various combinations of energy and technology. In this context, technology is often viewed as capital and know-how. To a large extent, energy and technology, capital, and know-how can substitute for one another. Replacing less efficient and dirty technology with more efficient and cleaner technology is the substitution of capital and know-how for energy. Capital investment, however, typically involves energy embedded in materials, manufacturing, and construction, as well as labour and know-how.

The core business of the energy sector has traditionally involved delivering electricity to homes and businesses, natural gas to industries, and gasoline to gas stations. In the past, electricity supply—especially electrification of unserved areas—was a matter of sociopolitical development strategy. As a matter of state importance, energy supply was often directed by a regional utility under essentially monopolistic conditions. More recently, energy sector liberalisation has turned strategic goods into commodities, changing the sector from selling kilowatt-hours or litres of gasoline to selling energy services. With competition among suppliers, energy companies will become increasingly active in providing energy services, which may also include end-use technologies.

Demand for energy services

The structure and size of the energy system are driven by the demand for energy services. Energy services, in turn, are determined by driving forces, including:

- Economic structure, economic activity, income levels and distribution, access to capital, relative prices, and market conditions.
- Demographics such as population, age distribution, labour force participation rate, family sizes, and degree of urbanisation.
- Geography, including climatic conditions and distances between major metropolitan centres.
- Technology base, age of existing infrastructure, level of innovation, access to research and development, technical skills, and technology diffusion.
- Natural resource endowment and access to indigenous energy resources.
- Lifestyles, settlement patterns, mobility, individual and social preferences, and cultural mores.

- Policy factors that influence economic trends, energy, the environment, standards and codes, subsidies, and social welfare.
- Laws, institutions, and regulations.

The structure and level of demand for energy services, together with the performance of end-use technologies, largely determine the magnitude of final energy demand. The amount of final energy per unit of economic output (usually in terms of gross domestic product, or GDP), known as the final energy intensity, is often used to measure the effectiveness of energy use and the consumption patterns of different economies. Economies with a large share of services in GDP and a large share of electricity in the final energy mix usually have lower final energy intensities than do economies based on materials and smokestack-based industries and fuelled by coal and oil. The final energy demand mix, the structure and efficiency of energy supply (resource extraction, conversion, transmission, and distribution), domestic resource availability, supply security, and national energy considerations then determine primary energy use.

Global primary energy use expanded by about 2 percent a year in 1970–98 (table 1.1). This growth rate fell to just under 1 percent a year in 1990–98 as a result of regional differences in socioeconomic development. First, the severe economic collapse of transition economies in Eastern Europe and the former Soviet Union reduced income by 40 percent and primary energy use by 35 percent between 1990 and 1998. Second, the rapid growth experienced by developing countries in the 1980s slowed in the early 1990s and slowed even more during the financial crisis of 1997–98. Third, among OECD regions, energy growth exceeded the long-term global average only in Pacific OECD countries. In North America, despite continued economic expansion and the availability of inexpensive energy services throughout the 1990s, total energy use grew by just 1.4 percent a year (the same as the OECD average). If corrected for weak economic performance in transition economies and the 1997–98 financial crisis, global energy use would have continued to grow by 2 percent a year throughout the 1990s.

Energy use by developing countries has increased three to four times as quickly as that by OECD countries—the result of life-style changes made possible by rising incomes and higher population growth. As a result the share of developing countries in global commercial energy use increased from 13 percent in 1970 to almost 30 percent in 1998. On a per capita basis, however, the increase in primary energy use has not resulted in more equitable access to energy services between developed and developing countries. (Annex C provides energy data and trends related to the discussion in this chapter, disaggregated by country and region.)

In Africa per capita energy use has barely increased since 1970 and remains at less than 10 percent of per capita use in North America (annex table C2). The same is true for Asia despite a near-doubling in per capita energy use since 1970. In essence this means that most Africans and Asians have no access to commercial energy. Latin America saw little improvement, while China and especially the Middle East made above-average progress in providing access to modern energy services. Energy use in non-OECD Europe and the former Soviet Union has been affected by economic restructuring, which in the former Soviet Union led to negative per capita growth in energy use between 1971 and 1997. Per capita energy use stayed nearly constant in North America, while substantial growth occurred in the Pacific OECD.

TABLE 1.1. COMMERCIAL PRIMARY ENERGY USE BY REGION, 1970–98[a]

Region	1970 (exajoules)	1980 (exajoules)	1990 (exajoules)	1998 (exajoules)	1998 as share of world total (percent)	Annual growth rate, 1970–98 (percent)	Annual growth rate, 1970–80 (percent)	Annual growth rate, 1980–90 (percent)	Annual growth rate, 1990–98 (percent)
North America	74.7	85.6	93.4	104.3	29.4	1.2	1.4	0.9	1.4
Latin America	5.7	9.2	11.3	15.1	4.3	3.6	4.9	2.1	3.7
OECD Europe[b]	51.6	61.9	66.5	70.1	19.7	1.1	1.8	0.7	0.7
Non-OECD Europe[c]	3.6	6.1	6.5	4.8	1.3	1.0	5.3	0.5	-3.8
Former Soviet Union	31.8	47.2	58.5	37.5	10.6	0.6	4.0	2.2	-5.4
Middle East	3.0	5.6	10.6	15.4	4.3	6.0	6.4	6.6	4.7
Africa	2.9	5.6	8.9	11.0	3.1	4.8	6.6	4.8	2.7
China	9.8	17.8	28.5	36.0	10.1	4.8	6.2	4.8	3.0
Asia[d]	6.0	10.6	18.8	28.1	7.9	5.7	5.9	5.9	5.2
Pacific OECD[e]	14.1	19.4	26.0	32.8	9.2	3.0	3.2	3.0	2.9
World total	**203.2**	**269.0**	**328.9**	**354.9**	**100.0**	**2.0**	**2.8**	**2.0**	**1.0**
OECD countries	140.4	166.9	185.9	207.2	58.4	1.4	1.7	1.1	1.4
Transition economies	35.4	53.3	65.0	42.3	11.9	0.6	4.2	2.0	-5.2
Developing countries	27.4	48.8	78.0	105.5	29.7	4.9	5.9	4.8	3.8

a. Excluding commercial biomass. b. Includes Czech Republic, Hungary, and Poland.c. Excludes the former Soviet Union. d. Excludes China. e. Australia, Japan, Republic of Korea, and New Zealand.

Source: BP, 1999.

Regional energy use is even more inequitable when viewed in terms of per capita electricity use. The difference between the least developed countries (83 kilowatt-hours per capita) and the OECD average (8,053 kilowatt-hours per capita) is two orders of magnitude (see annex table C.2).

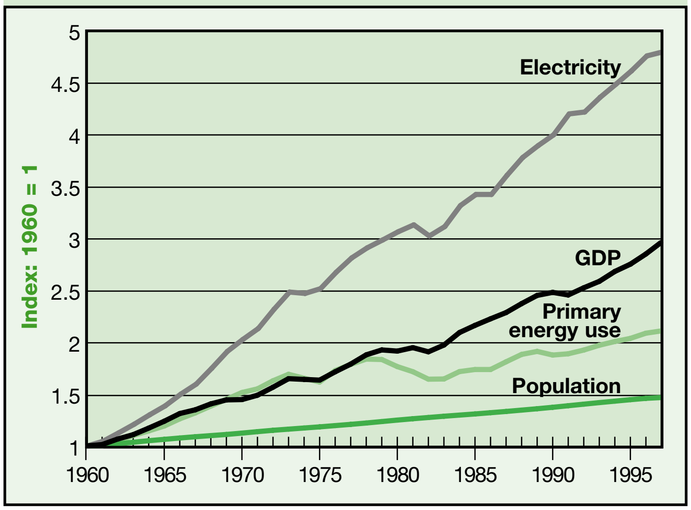
The link between energy use and economic activity is neither static nor uniform across regions. In the past, energy and economic development were closely related. But this relationship does not necessarily hold at higher levels of economic development. During 1960–78 changes in primary energy use and GDP grew at the same rate in OECD countries (figure 1.1). Thereafter, a change in elasticity between energy and economic activity suggests that the often-postulated one-to-one relationship between primary energy use and economic activity can be changed, at least temporarily. Because of its versatility, convenience, cleanliness (at point of use), and productivity-enhancing features, the increase in electricity use has outpaced GDP growth in all regions—often by a large margin. In addition, the efficiency of converting electricity from final energy to energy services is the highest of all fuels.

Energy transformation is the fastest-growing sector in all countries except transition economies, generally followed by transportation. Electricity generation dominates energy transformation, reflecting the continued importance of electricity for economic development. Oil refining, coal transformation (coking), gasworks, centralised heat production, transmission, and distribution losses account for the rest of the energy used by energy transformation.

Energy trade patterns and globalisation

The growing share of traded goods and services in gross world product reflects a continued shift towards integrated global commodity markets. This share approached 43 percent in 1996, up from 25 percent in 1960. The value share of energy in trade peaked in 1979 at almost 14 percent, then fell to 3–5 percent in the 1990s.

FIGURE 1.1. CHANGES IN GDP, POPULATION, PRIMARY ENERGY USE, AND ELECTRICITY USE IN OECD COUNTRIES, 1960–97



Source: IEA, 1999.

Still, the world energy system has become more integrated, as evidenced by the rising share of energy crossing borders before reaching final consumers. Energy trade slipped to 40 percent of primary energy use in 1985 (down from 50 percent in 1970) but rebounded after the collapse in oil prices in 1986. By the end of the 20th century this share was approaching 55 percent.

The fast-growing Asian economies contributed significantly to this increase. Their energy imports tripled between 1985 and 1997, reaching 13 percent of world energy imports. The share of OECD countries in global energy trade dropped 6 percentage points thanks to stepped-up intraregional trade and increased domestic production of oil (accounting for 13 percent of domestic oil production in 1990, up from 6 percent in 1985) and gas (30 percent of domestic gas production in 1985). OECD countries in Europe cut their share of global imports from 25 percent in 1985 to 16 percent in 1997, while North America doubled its share to 8 percent over the same period.

Global energy trade remains dominated by crude oil and oil products. Despite steady growth in coal trade and accelerated penetration of natural gas in the 1990s, the share of crude oil and oil products in trade only fell from 90 percent in 1971 to 77 percent in 1997. While trade in coal, natural gas, and even oil products expanded largely unaffected by world oil market prices, trade in crude oil definitely responds—though with a lag—to market price changes. Thus crude oil remains the world's swing fuel, with Middle Eastern countries as the swing supplier despite the fact that the Middle East has the lowest production costs.

Crude oil and oil products

Developing countries have almost doubled their share of crude oil and oil product imports since 1979. While other major importers such as Western Europe and Japan have reduced or held steady their share of the global oil trade, the U.S. thirst for oil has reached an all-time high, accounting for 25 percent of global oil trade. In 1998 some 46 percent of oil trade originated in the Middle East—up from 38 percent in 1985. The region is on track to regain market shares of well above 50 percent. Its low production costs (on average, less than $5 a barrel) exposes investments in oil production capacity elsewhere to above-average risks. It appears that Organisation of the Petroleum Exporting Countries (OPEC) countries have regained their monopoly power lost in 1986, and can control oil market prices in either direction.

For importing countries, concerns about oil import dependence and supply security appear to have given way to market forces and high expectations that new exploration and development will bring new oil to the market at a rate commensurate with demand. Moreover, in the wake of globalisation and non-polarisation, quasi-open access to OPEC oil has accelerated the shift of oil from a strategic good to a commodity, further lowering supply security concerns.

Still, the world oil market remains fragile. In March 1999 OPEC countries cut production by 85 million tonnes a year, or 2.5 percent of world oil production. This was in addition to an earlier cut of 125 million tonnes. As a result of strong world oil demand, including that from the rebounding Asian economies and the surging U.S. economy, market prices almost tripled within about a year. (World market prices for API Gravity 2 oil were $9.39 a barrel in December 1998 and $27.55 a barrel in March 2000.)

Since 1990 electricity rates have declined steadily, especially in countries where electricity market deregulation has been or is about to be introduced.

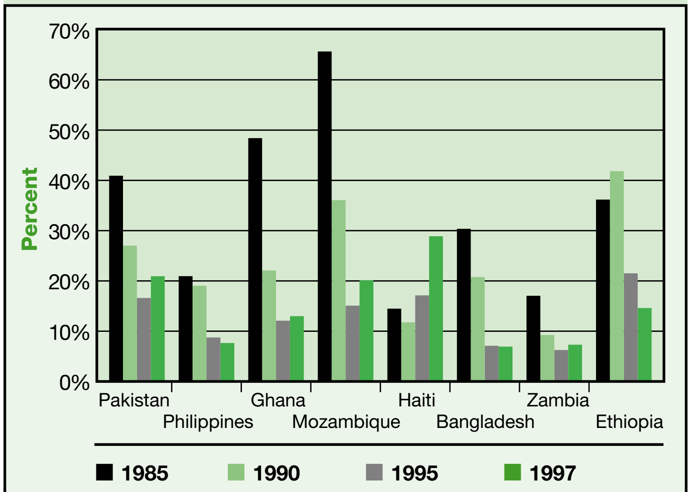
The impact of oil market prices or of high dependence on oil imports (or both) on the economies of several developing countries is shown in figure 1.2. In several countries oil imports absorb a large share of export earnings. The low oil market prices of the mid-1990s benefited these economies relative to 1985 (the year before oil prices collapsed) and 1990 (when prices soared during the Gulf war). The pattern for Haiti differs from those of the other countries in figure 1.2. There the share of export earnings spent on oil imports has more than doubled since 1985. The 1999 hike in oil prices will likely absorb similar shares of export earnings as in 1985 and 1990.

Coal

World coal production runs about 4,500 million tonnes, equivalent to some 2,230 million tonnes of oil equivalent (Mtoe), 210 Mtoe of which corresponds to steam coal trade. In recent years coal exports have grown by 4 percent a year. There is no indication that demand will outstrip supply in the foreseeable future. Production capacity is well developed, and new market entrants (Colombia, Kazakhstan, Russia, Venezuela) are eager to join the trade.

Over the past 20 years a quasi-unified coal market has emerged in which the United States has assumed the role of marginal supplier. Indeed, U.S. capacities are among the world's highest-cost supplies. Everything else being equal, prices tend to gravitate towards the production costs of the marginal producer. Because productivity advances determine the cost of U.S. production, U.S. productivity levels determine the world price of coal.

FIGURE 1.2. OIL IMPORTS AS A SHARE OF EXPORT EARNINGS IN VARIOUS DEVELOPING COUNTRIES, 1985–97



Source: World Bank, 1999.

Natural gas

Unlike oil and coal markets, natural gas has yet to play a significant role in global markets. Some 20 percent of global gas crosses borders before reaching final consumers. About 75 percent of that gas is traded by pipe between essentially neighbouring countries. Hence natural gas trade has developed primarily at the regional level or between adjacent regions. Pipeline transmission is capital-intensive and allows little flexibility in the choice of buyers and sellers. Still, pipeline gas is traded between production and consumption sites more than 4,000 kilometres apart. Three major regional gas trade markets have emerged:

- The almost fully integrated North American market, characterised by accelerated growth of Canadian exports to the U.S. market (from 26 Mtoe in 1990 to 79 Mtoe in 1998). There have also been minor exchanges between Mexico and the United States.
- The European market, with the following principal suppliers: the former Soviet Union (with a pipeline producing 108 Mtoe in 1998), Norway (pipeline producing 38 Mtoe), and the Netherlands (pipeline producing 33 Mtoe), and Algeria with minor liquefied natural gas supplies from Libya (pipeline and liquefied natural gas producing 47 Mtoe). Gas trade expanded by 2.7 percent a year in 1990–98.
- The Asian gas market is dominated by liquefied natural gas (which increased from 47 Mtoe in 1990 to 77 Mtoe in 1998). The main suppliers are Indonesia, Malaysia, Australia, Brunei, the United Arab Emirates, and Qatar. Japan, the Republic of Korea, China, and Taiwan (China) are the main customers.

A gas market has also begun to develop in Latin America, with exports from Bolivia to Argentina and Argentina to Chile.

Energy prices and taxes

Energy prices influence consumer choices and behaviour and can affect economic development and growth. High energy prices can lead to skyrocketing import bills, with adverse consequences for business, employment, and social welfare. Energy exporters benefit from high energy prices. High energy prices also stimulate exploration and development of additional resources, foster innovation, and encourage efficiency improvements.

While some impacts of energy prices are fairly steady, others are more transient. For example, higher absolute prices have had little impact on economic development in Japan and OECD countries in Europe relative to the much lower prices in the United States and some developing countries. The price hikes of the 1970s affected economic growth in all energy-importing countries, however. Thus it appears that economies are more sensitive to price changes than to price levels. But even price changes appear not to cause the turbulence of the past. The recent near-tripling in world oil market prices has, at least in OECD countries, not yet had any impact on economic development.

Market size and product mobility often favour investments in oil exploration and development over, for example, natural gas or energy efficiency.

Energy prices, which include taxes, must be clearly distinguished from costs, average costs from marginal costs, and contract markets from spot markets. Two types of exchange modes—contract markets and spot markets—prevail in most major energy markets. Contracts are long-term trade agreements between exporters and, in the case of oil, refineries. Contracts account for about 80 percent of traded oil. The prices associated with these contracts are usually not disclosed. Contract prices are quasi-fixed for the contract period but include certain adjustment mechanisms that account for major market changes.

The remaining 15–20 percent of international oil is traded in spot markets. Spot sales are more or less instantaneous sales of entire cargoes. Initially, spot market transactions served as a mechanism to clear markets for a small share of production that was not contracted or became available for other reasons—say, seasonal market fluctuations. The spot market has since become the principal mechanism for setting oil prices as well as an essential ingredient for managing risk.

Steam coal prices are less volatile than oil, which is one reason coal remains a popular fuel for electricity generation. In addition, coal can be significantly cheaper than natural gas and oil. While internationally traded energy prices are an important factor in the approximately $450 billion business (at $20 a barrel), the energy bills presented to users are considerably higher than the trade prices because most countries tax energy use. In general, OECD taxes on residential energy use are higher than those on industry. In some developing and transition economies taxes are higher for industry, usually as a cross-subsidy to provide energy services to the poor. Energy taxes and subsidies are an important tool for governments pursuing energy development objectives.

Since 1990 electricity rates have declined steadily, especially in countries where electricity market deregulation has been or is about to be introduced. Market liberalisation has a more profound impact on the electricity rates of industry than of households. Prices for light oil at the national level largely mirror movements in the global market price for oil. Light oil prices are much lower in India and other developing countries than in OECD countries, reflecting government subsidies.

Energy investments

Capital investment is a prerequisite for energy development. Energy system development and structural change are the results of investments in plants and equipment as well as in energy system infrastructure. Difficulties in attracting capital for energy investments may impede economic development, especially in the least developed countries. Although energy investments account for only a small share of the global capital market, the provision of the capital required to finance the growing needs of the energy sector cannot be assumed, especially in developing countries.

General features

The challenges of raising funds for energy investments include the perceived risk to investors and the uncertainty on rates of return. Returns on energy investments do not always compare well to those on other infrastructure investments. During 1974–92 electricity projects supported by the World Bank achieved average rates of return of 11 percent a year—while returns to urban development projects were 23 percent and to transport projects, 21 percent (Hyman, 1994). Also important is the allocation of funds within the energy sector. Rate of return considerations discriminate against small-scale, clean, and innovative energy supplies and against investments in energy efficiency. Market size and product mobility often favour investments in oil exploration and development over, for example, natural gas or energy efficiency.

Investments in energy plants, equipment, and infrastructure must be viewed in the context of economic growth, savings, and the size and degree of liberalisation of capital markets. The current average global savings rate is about 22 percent of GDP—21 percent in developed countries and 24 percent in developing countries. In transition economies recent declines in GDP have been matched by reduced savings, keeping the savings rate at about 20 percent (World Bank, 1999). Although energy investments as a share of total investments vary greatly among countries and between stages of economic development, an average of 1.0–1.5 percent of GDP is invested in energy. This share is expected to remain relatively stable.

Thus current energy investments amount to $290–430 billion a year. But such investments do not include investments in end-use devices and appliances, energy efficiency improvements in buildings, and so on. Including these investments doubles capital requirements.

Energy investments have long lives. Investments in electricity generating plants, refineries, and energy-related infrastructure made in the next 10 years will likely still be in operation in 2050 and beyond. Hence there is a fair amount of inertia with regard to the rate of change that can be introduced in the energy system. For example, the current global average conversion efficiency for coal-fired electricity generation is 34 percent and for gas-fired electricity generation, 37 percent. The best commercially available coal and gas power plants have much higher efficiencies: 43–48 percent for coal and 55–60 percent for natural gas.

Given the longevity of the existing capital stock, it is unlikely that the global average will reach, say, 45 percent for coal-fired electricity by 2050 unless the most efficient plants are adopted universally. But most efficient does not always mean least cost—low-cost domestic coal can be burnt more economically in a medium-efficient plant than in a high-efficient but more capital-intensive alternative.

The efficiency of electricity generation also varies widely among regions. The Middle East introduced coal for electricity generation in the early 1980s and, because most coal is imported, adopted the latest coal combustion technology. As a result the region's average conversion efficiency exceeds that of OECD countries. Another aspect affecting efficiency is the introduction of sulphur and nitrogen oxide abatement equipment, which tends to reduce efficiency (as in Asia and Africa).

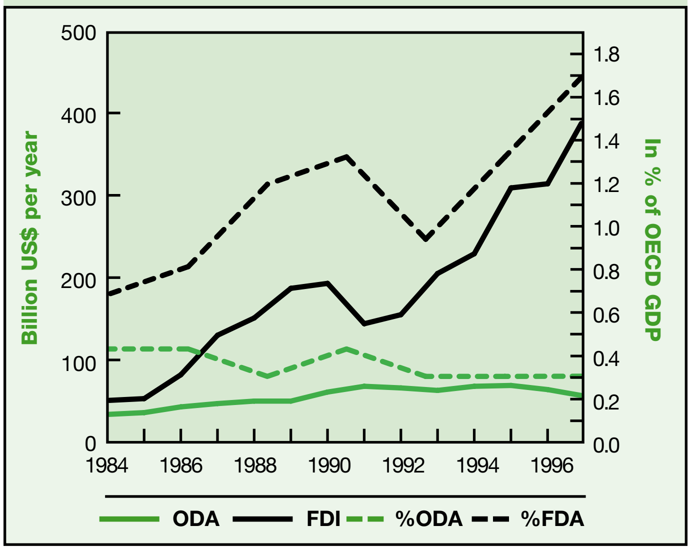
Capital flows

The globalisation of economic production has led to an acceleration of capital flows. Indeed, capital markets have been growing faster than GDP for some time, and this trend is unlikely to change. Annual global energy investments account for about 7 percent of international credit financing, which is about $3.6 trillion (Hanke, 1995). With capital markets growing relative to GDP, and assuming relatively stable future energy investment ratios, capital market size does not appear to be a limiting factor for energy sector finance.

Scarce public funds, especially in developing countries, are sought by many needy projects ranging from rural development, education, and health care to energy supply. Because energy supply, more than any other alternative, is often seen as more readily capable of generating revenues early on, energy investments are increasingly viewed as a private sector affair. Yet private funds are not flowing into most developing countries.

Foreign direct investment approached $400 billion in 1997, up from $50 billion in 1984, and accounted for 1.8 percent of OECD GDP (up from 0.6 percent in 1984; figure 1.3). Foreign direct investment in energy projects is estimated at 5–15 percent of the total (Victor, 2000). Foreign direct investment is generally commercially motivated, with the sponsor of investments expecting not only to recover the initial capital but also counting on competitive returns. This cannot always be guaranteed in developing countries with potentially fragile governments or the absence of free markets. Indeed, 25 countries received 89 percent of global foreign direct investment in 1996, and only 10 of these are developing countries—none are among the 47 least developed countries. Brazil, China, and Mexico are the only developing countries to receive more than 2 percent of the world total.

FIGURE 1.3. FOREIGN DIRECT INVESTMENTS AND OFFICIAL DEVELOPMENT ASSISTANCE, 1984–97, IN US$ AND AS SHARE OF OECD GDP



Source: World Bank, 1999.

In contrast to foreign direct investment, official development assistance is meant as development aid in the form of grants. Official development assistance increased from $34 billion in 1984 to $69 billion in 1995 but slipped to $56 billion in 1997, or 0.25 percent of OECD GDP—a far cry from the 0.7 percent target agreed to by developed countries (see figure 1.3).

Against these recent developments in international financial and capital flows, prospects for financing energy projects in developing countries generally look bleak. Most foreign investors lack confidence in the ability of developing country energy projects to provide stable (and competitive) returns until the investment has been recovered. Hence, until the economic risk to foreign investors can be eliminated (through deregulated energy and financial markets, steady revenue generation through bill collection, firm policies on profit transfers, and the like), developing countries will have to continue to finance their energy development from domestic savings. ■

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