part III

Energy and Major Global Issues

Part III analyses the linkages between energy and the economy, social and health issues, environmental protection, and security, and describes aspects of energy use that are incompatible with the goal of sustainable development. It shows that:

- **Access to affordable energy services is fundamental to human activities, development, and economic growth. It is access to energy services, not energy supply *per se*, that matters.**
- **More than two billion people cannot access affordable energy services based on efficient use of gaseous and liquid fuels, and electricity. Without access to energy, their opportunities for economic development and improved living standards are constrained. Women and children, relatively more dependent on traditional fuels, suffer disproportionately.**
- **Wide disparities in access to affordable commercial energy and energy services in both urban centres and rural areas are inequitable, run counter to the concept of human development, and threaten social stability. Access to decentralised small-scale energy technologies is an important element of successful poverty alleviation.**
- **The environmental impacts of a host of energy-linked emissions – including suspended fine particles and precursors of acid deposition – contribute to local and regional air pollution and ecosystem degradation. Human health is threatened by high levels of pollution resulting from particular types of energy use at the household, community, and regional levels.**
- **Emissions of anthropogenic greenhouse gases, mostly from the production and use of energy, are altering the atmosphere in ways that are expected to affect the climate. There is new and stronger evidence that most of the warming observed over the last fifty years**

is attributable to human activities. Within a few years, it will be too late to avoid doubling the concentration of carbon dioxide in the atmosphere.

- **Dependence on imported fuels leaves many countries vulnerable to disruption in supply, which might pose physical hardships and economic burdens; the weight of fossil fuels imports on the balance of payments is unbearable for many poorer countries. The existing energy system is heavily dependent on fossil fuels, which are geographically concentrated in a few regions of the world.**

Finding ways to expand energy services while simultaneously addressing the environmental impacts associated with energy use represents a critical challenge to humanity. Major changes are required in energy system development world-wide. The resources and technology options available to meet these challenges – energy efficiency, renewable energy sources, and advanced energy technologies – are analysed later in this volume.

Energy and Social Issues

The relationship between energy and social issues is two-way. The ability to pay for energy services and knowledge of what is available and how best to apply it will affect the level of demand and type of energy services used. Conversely, the quality (cleanliness, reliability, and convenience) and level of access (availability, affordability, and variety) of energy services have an effect on social issues. Lack of access to energy services is closely linked to a range of social concerns, including poverty, lack of opportunities, urbanisation, poor health, and a lack of education for women in particular.

As mentioned in Part I, the WSSD Plan of Implementation recognises the importance of improved access to reliable and affordable energy services to facilitate the achievement of the Millennium Development Goals and the link between access to energy services and poverty reduction. Box 1 shows some ways that energy can help achieve the MDGs. (For more examples of the direct and indirect relationships between energy and the MDGs, see Annex I.)

Poverty is the overriding social consideration for developing countries. Some 1.3 billion people in the developing world live on less than $1 per day. Income measurement alone, however, does not fully capture the misery and the absence of choice that poverty represents. The energy available to poor people – especially their reliance on traditional fuels in rural areas – is not supportive of the development and income generation needed to alleviate poverty.

World-wide, two billion people rely on traditional biomass fuels for cooking and/or have no access to modern energy services. For these people, cooking indoors with poorly vented stoves has significant health impacts. Hundreds of millions of people – mainly women and children – spend several hours per day in the drudgery of gathering firewood and water, often from considerable distances, for household needs. Because of these demands on their time and physical energy, women and children often have no opportunities for education and other productive activities, while their health suffers.

The two billion people lacking access to electricity have inadequate lighting and few labour-saving devices, as well as limited telecommunications and possibilities for commercial enterprise. Greater access to electricity, modern fuels, and clean, efficient technologies such as improved stoves for cooking can enable people to benefit from both short- and long-term advances in their quality of life. Table 3 summarises some of the specific improvements that may result from increased access.

BOX 1. ENERGY AND THE MILLENNIUM DEVELOPMENT GOALS

Energy services can play a variety of direct and indirect roles in helping to achieve several MDGs:

To halve extreme poverty. Access to energy services facilitates economic development – micro-enterprise, livelihood activities beyond daylight hours, locally owned businesses that create employment – and assists in bridging the "digital divide".

To reduce hunger and improve access to safe drinking water. Energy services can improve access to pumped drinking water and provide fuel for cooking the 95 percent of staple foods that need cooking before they can be eaten.

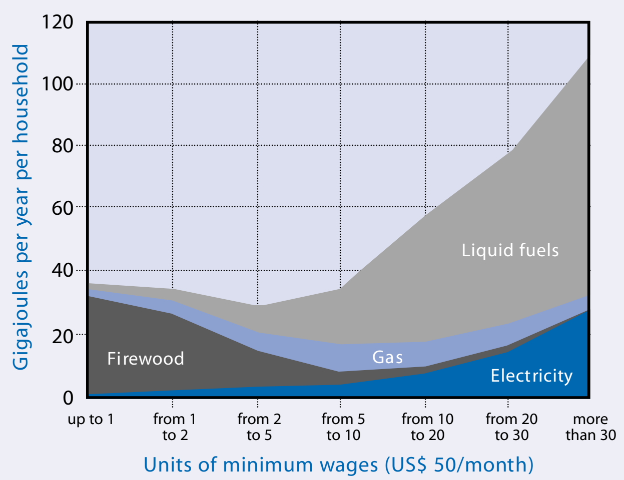
To reduce child and maternal mortality, and to reduce diseases. Energy is a key component of a functioning health system, contributing, for example, to lighting operating theatres, refrigerating vaccines and other medicines, sterilising equipment, and providing transport to health clinics.

To achieve universal primary education, and to promote gender equality and empowerment of women. Energy services reduce the time spent by women and children (especially girls) on basic survival activities (gathering firewood, fetching water, cooking, etc.); lighting permits home study, increases security, and enables the use of educational media and communications in schools, including information and communication technologies (ICTs).

To ensure environmental sustainability. Improved energy efficiency and use of cleaner alternatives can help to achieve sustainable use of natural resources, as well as reduce emissions, which protects the local and global environment.

Source: DFID, 2002.

FIGURE 9. AVERAGE ENERGY DEMAND BY INCOME SEGMENT IN BRAZIL, 1998



Source: E. Almeida and A. De Oliveira. "Brazilian Life Style and Energy Consumption," in Energy Demand, Life Style Changes and Technology Development *(London: World Energy Council, 1995).*

Low-income households in developing countries typically use traditional fuels and inefficient technologies. Figure 9 shows the average primary energy demand for various fuels as a function of income levels in Brazil, indicating that higher income segments of the population increasingly rely on modern fuels as income grows.

For low-income households, firewood is the dominant fuel. At higher incomes, commercial fuels and electricity replace wood, offering greater convenience, energy efficiency, and cleanliness. Because convenient, affordable energy can contribute to a household's productivity and income-generating potential, its availability can help families and communities break out of the cycle of poverty.

It is widely understood that population growth has a direct impact on energy by increasing demand. It is less widely understood that access to adequate energy services is associated with increased life expectancy and reduced child mortality and can shift the relative benefits and costs of fertility towards a lower number of desired births in a family. However, this lower number of desired births can only be realised if effective fertility reduction techniques are available. An acceleration of the demographic transition to low mortality and low fertility (as has occurred in industrialised countries) depends on crucial developmental tasks, including improving the environment, educating women, and ameliorating the extreme poverty that may make child labour a necessity. All these tasks have links to the availability of affordable clean energy services.

TABLE 3. ENERGY-RELATED OPTIONS TO ADDRESS SOCIAL ISSUES

Social Challenge	Energy Linkages and Interventions
Alleviating poverty in developing countries	■ Improve health and increase productivity by providing universal access to adequate energy services – particularly for cooking, lighting, and transport – through affordable, high-quality, safe, and environmentally acceptable energy carriers and end-use devices. ■ Make commercial energy available to increase income-generating opportunities.
Increasing opportunities for women	■ Encourage the use of improved stoves and liquid or gaseous fuels to reduce indoor air pollution and improve women's health. ■ Support the use of affordable commercial energy to minimise arduous and time-consuming physical labour at home and at work. ■ Use women's managerial and entrepreneurial skills to develop, run, and profit from decentralised energy systems.
Speeding the demographic transition (to low mortality and low fertility)	■ Reduce child mortality by introducing cleaner fuels and cooking devices and providing safe, potable water. ■ Use energy initiatives to shift the relative benefits and costs of fertility – for example, adequate energy services can reduce the need for children's physical labour for households chores. ■ Influence attitudes about family size and opportunities for women through communications made accessible by modern energy carriers.
Mitigating the problems associated with rapid urbanisation	■ Reduce the "push" factor in rural-urban migration by improving energy services in rural areas. ■ Exploit the advantages, and moderate the disadvantages, of high-density settlements through land-use planning. ■ Provide universal access to affordable multi-modal transport services and public transportation. ■ Take advantage of new technologies to avoid energy-intensive, environmentally unsound development paths.

Energy technology choices in developing countries have important equity implications. Investments in centralised, capital-intensive conventional energy enterprises such as coal-fired power-generation and large dams largely benefit high- and middle-income urban communities, commercial establishments, and industries through electricity distributed through power grids. Poor, dispersed rural communities that are often far from the grid rarely benefit from such investments. Even in urban areas, low-income neighbourhoods and shantytowns are often not connected to the grid. A growing number of studies find that renewable and other decentralised small-scale energy technologies (such as diesel motors and hybrids) are important options for poverty alleviation, particularly technologies that are locally made and that operate using locally available fuels (e.g., hydro power, wind power, solar power, and modern biomass resources). These decentralised energy technologies can be a source of jobs, employment, and enterprise creation for both the rural and urban poor in developing countries, and can be competitive and affordable in isolated areas or other niche markets.

More than two billion people cannot access affordable energy services. Women and children suffer disproportionately.

The increasing concentration of people in urban centres is another key development issue linked to energy. Although the general trend towards urbanisation has many components and may be inevitable, providing more options to rural residents through energy interventions could potentially slow migration and reduce pressure on rapidly growing cities. Energy inputs can improve agricultural productivity, generating better rural incomes and higher value added in this sector. Productive uses of energy provide employment opportunities and reduce the necessity to migrate to urban areas for employment. Productive uses allow income-generating opportunities that can help pay for the energy services, thus making them more affordable and sustainable. There is a clear need for mechanisms to cut the transaction costs between a large number of invisible potential consumers and a discrete number of suppliers of energy services, thereby promoting investment in local productive chains.

In developing countries, addressing the energy needs of the poor, who represent a large majority, will require major structural changes. In industrialised countries, on the other hand, adequate access to affordable energy is problematic only for a minority, and thus is more amenable to social policy solutions. Throughout the world, however, poor households pay a larger fraction of their incomes for energy than do the rich, and so are vulnerable to the effects of rapid increases in the price of energy. Increases in the price of oil in the winter of 1999/2000, for example, posed a hardship for many people, including some in industrialised countries. In addition to paying a larger fraction of their income on energy services, poor households often pay more per unit of energy than rich households do. They have few energy services available to them and have little choice but to use inefficient fuels and technologies. The role of energy efficiency in improving this situation should not be overlooked.

A full menu of energy options needs to be considered in order to achieve the MDGs and lift the poor out of poverty. Renewable energy resources have an important role to play, but traditional biomass resources and fossil fuels coupled with improved, efficient, cleaner technologies will play a major role in providing energy services to the poor for decades to come. Poor people need to be empowered and included in the decision making process, so they can influence the selection of affordable, reliable, and clean energy services that can most appropriately meet their needs. Participatory approaches and managing the expectations of communities are important if the energy services are to be accepted by those communities and maintained well enough to provide sustainable energy services for the future.

Eradicating poverty is a long-term goal of development. But long before that goal is achieved, convenient and affordable energy services could dramatically improve living standards and offer more opportunities to people. Today's inequity is unsustainable. Satisfying the energy service needs of the poor with modern technologies has the potential to improve standards of living and health, and to create new jobs and business opportunities. Allowing one third of the world's population to continue to endure the constraints associated with traditional energy is unacceptable from a humanitarian and a moral standpoint.

Energy and Economic Issues

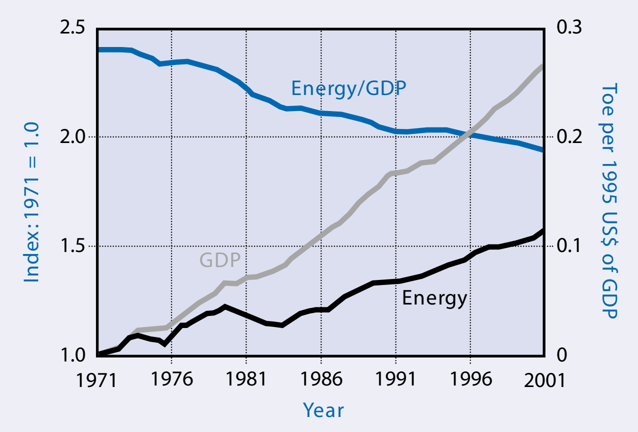
If the global growth rate of about 1.5 percent per year in primary energy use continues (Table 2), total energy use will double between 2000 and 2040, and triple by 2060. In the past thirty years, developing countries' commercial energy use has increased three and a half times as fast as that of OECD countries; energy use has increased even faster in China. This is partly the result of lifestyle changes made possible by rising personal incomes, coupled with higher population growth rates and a shift from traditional to commercial energy in developing countries. It is also partly the result of a shift towards less energy-intensive production and consumption patterns in the OECD countries. On a per capita basis, however, the increase in total primary energy use has not resulted in notably more equitable access to energy services between industrialised and developing countries. Clearly, more energy will be needed to fuel global economic growth and to help deliver opportunities to the billions of people in developing countries who do not have access to adequate energy services and who live on less than $2 a day. The wide gap in per capita consumption of energy services between industrialised and developing countries will not last indefinitely, and there will be considerable pressure on the available physical and human energy resources.

However, the amount of additional energy required to provide the energy services needed in the future will depend on the efficiency with which the energy is produced, delivered, and used. Energy efficiency improvements could help reduce financial investments in new energy supply systems, as they have over the past two hundred years. The degree of interdependence between economic activity and energy use is neither static nor uniform across regions. Energy intensity (the ratio of energy use to GDP) often depends on a country's stage of development. In OECD countries, which enjoy abundant energy services, growth in energy demand is less tightly linked to economic production than it was in the past (Figure 10).

A detailed, long-term analysis of energy intensity for a number of countries reveals a common pattern of energy use driven by the following factors:

- The shift from traditional to commercial forms of energy, industrialisation, and motorisation initially increases the commercial energy/GDP ratio.
- As industrialisation proceeds and incomes rise, saturation effects, as well as an expansion of the service sector (which is less energy intensive), decrease the ratio of commercial energy to GDP after it reaches a peak. Many countries have passed this point of maximum energy intensity, but low-income developing countries have not.
- Given world-wide technology transfer and diffusion, energy efficiency improvements can be the main limiting factor in the growth of energy demand arising from increasing populations and growing production and incomes.
- The more efficient use of materials in better-quality, well-designed, miniaturised products, the recycling of energy-intensive materials, and the saturation of bulk markets for basic materials in industrialised countries contribute to additional decreases in energy intensity.
- In developing countries, technological leapfrogging (i.e., bypassing some of the steps followed in the past in industrialised countries and jumping directly to modern technologies) to the use of highly efficient appliances, machinery, processes, vehicles and transportation systems, and other energy technologies, offers considerable potential for energy efficiency improvements.
- In transition economy countries, the decoupling of energy costs and prices, the promotion of energy rather than energy services, and the fact that energy use was often not even metered (and thus not paid for in relation to consumption levels) resulted in low energy efficiency and high energy intensity for the level of GDP.

FIGURE 10. GDP AND PRIMARY ENERGY USE IN OECD COUNTRIES, 1971-2001

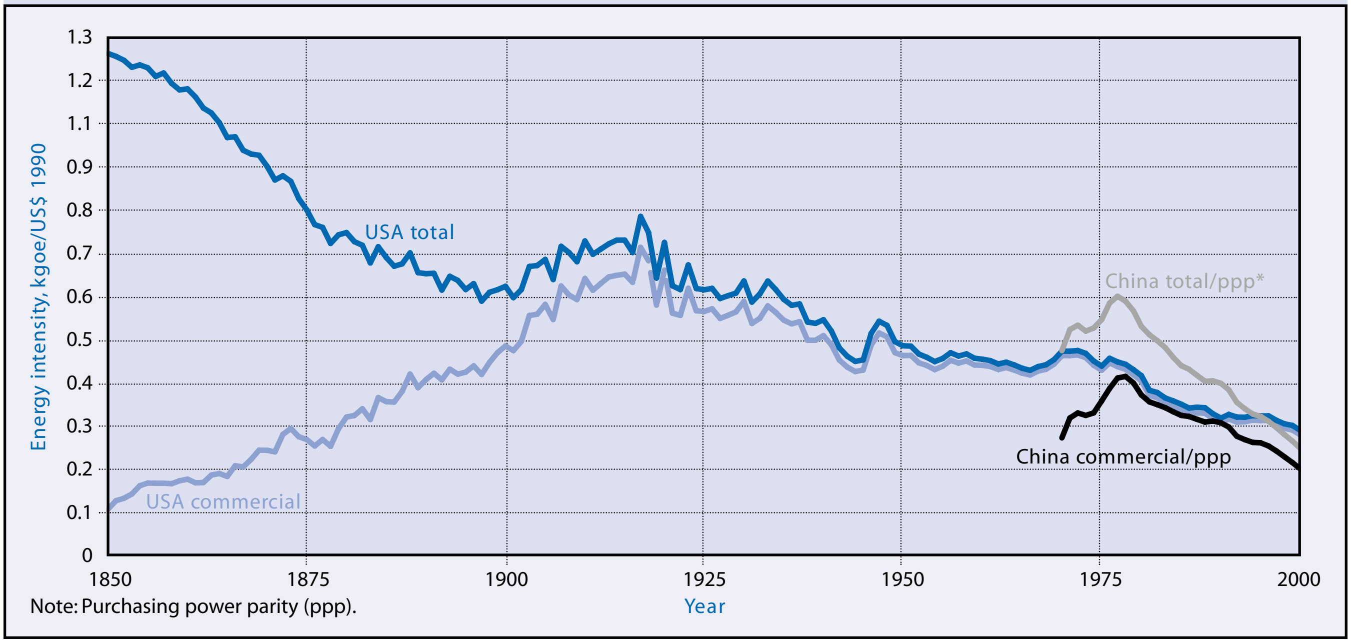


Sources: IEA, 2002a and 2002b.

These drivers are leading to a common pattern of energy use per unit of GDP in industrialised and developing countries; the U.S. experience illustrates this pattern (Figure 11). While initial costs for more energy efficient technologies are often higher than for less energy efficient ones, a life-cycle cost analysis, incorporating the savings from using less energy, shows lower costs. Therefore, in many countries, there are good reasons to adopt – early in the process of development – highly efficient appliances, machinery, industrial processes, vehicles, and transportation systems, thus "leapfrogging" some stages in the development process. China, for example, is following this route; energy intensity (measured in terms of energy use per unit of currency in purchasing power parity) has been falling rapidly since 1975.

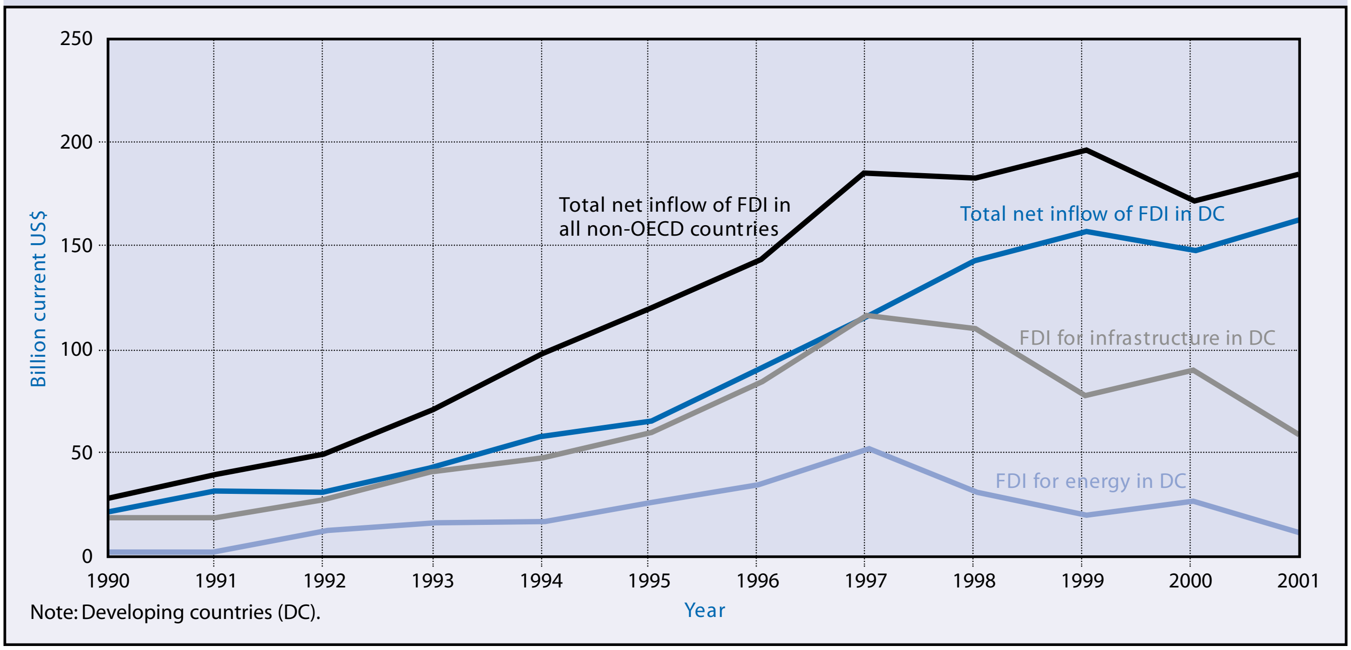
Energy prices influence consumer choices and behaviour and can affect economic development and growth. High energy-import prices can lead to increasing import bills, with adverse consequences for business,

FIGURE 11. ENERGY INTENSITY IN THE UNITED STATES (1850-2000) AND CHINA (1970-2000)



Source: N. Nakićenović and E. Slentoe (private communication).

FIGURE 12. NET INFLOW OF FOREIGN DIRECT INVESTMENT, 1990-2001



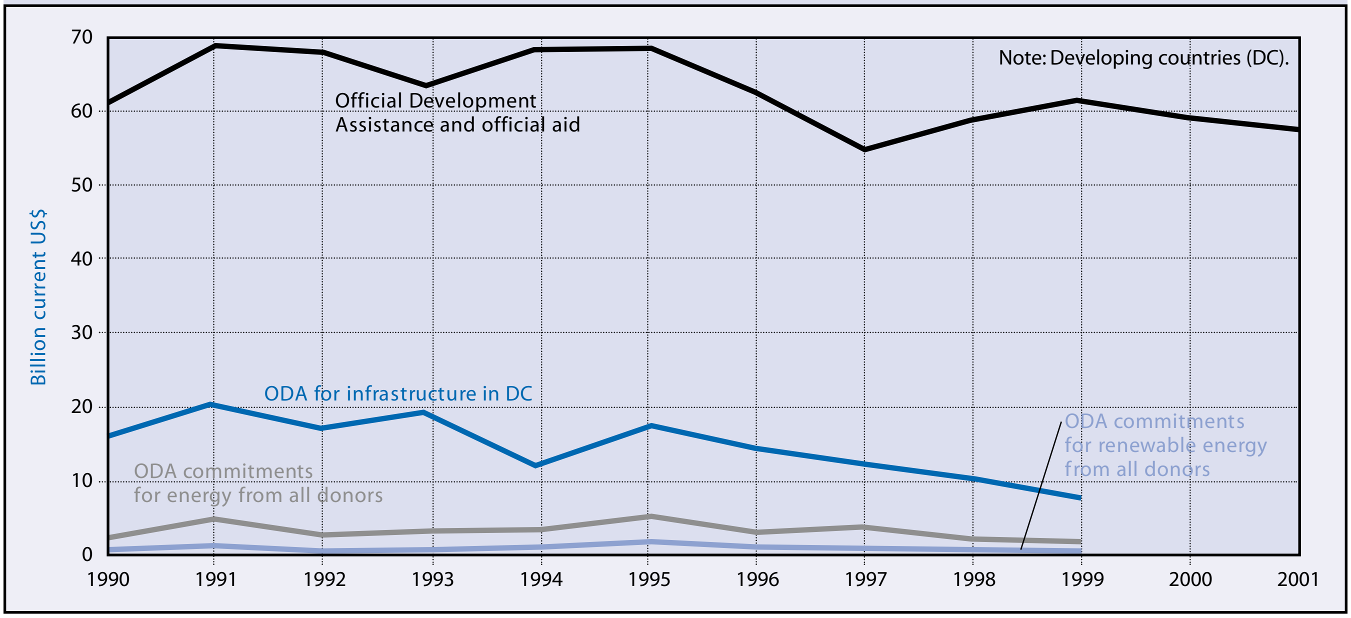
Source: World Bank, 2002, 2003; World Bank, Private Participation in Infrastructure (PPI) Project Database, http://rru.worldbank.org/ppi.

employment, and social welfare. High energy prices could also stimulate exploration and development of additional resources, create a pull for innovation, and provide incentives for efficiency improvements.

Although some impacts of energy prices are fairly steady, others are more transient. For example, different absolute price levels appear to have had little effect on economic development in European countries or Japan relative to the much lower energy prices in the United States and some developing countries. What affected economic growth in all energy-importing countries were the price hikes of the 1970s.

Capital investment is a prerequisite for energy development. Energy system development and structural

FIGURE 13. OFFICIAL DEVELOPMENT ASSISTANCE PROVIDED TO RECIPIENT COUNTRIES, 1990-2001



Source: World Bank, 2002, 2003; World Bank, Private Participation in Infrastructure (PPI) Project Database, http://rru.worldbank.org/ppi.

change are the results of investment in plants, equipment, and energy system infrastructure. Difficulties in attracting capital for energy investment may impede economic development, especially in the least developed countries. Scarce public funds, especially in developing countries, are needed for projects ranging from rural development, education, and health care to energy supplies. Because energy supply is often seen as more capable of generating early revenues than other alternatives, energy investments are increasingly viewed as a private sector matter. Yet private funds are not flowing into many developing countries for a variety of reasons, especially because investors perceive the risks as too high and traditional financing approaches are concerned about capital return and less sensitive to developing-country needs. Time frames for evaluating returns on large infrastructure investments are often too long to attract investment capital seeking short-tem financial returns.

World foreign direct investment (FDI) net inflows to all sectors approached $1,162 billion in 2000 – up from $200 billion in 1990. Foreign direct investment net inflows to developing countries grew from $25 billion to $171 billion in the same period, and increased again to $184 billion in 2001 (Figure 12). Foreign direct investment is generally commercially motivated, and investors not only expect to recover the initial capital but also count on competitive returns. These outcomes may be viewed as too risky in developing countries with potentially fragile governments or without free markets. In fact, very little foreign direct investment reaches the least developed countries. The bulk of foreign direct investment flows are concentrated in a discrete number of developing countries such as China and Brazil.

Unlike foreign direct investment, official development assistance (ODA) declined slightly relative to gross world product in the period 1997-2001 (Figure 13). In 2001, official development assistance from donor countries totalled $57 billion or 0.26 percent of their combined GDP. These numbers are down from over 0.3 percent of GDP in the 1980s, although industrialised countries have in principle agreed to a target of providing 0.7 percent of GDP as ODA.

Against this backdrop, financing is inadequate for energy projects in developing countries. Until the economic risks to foreign investors can be managed (for example, through clear and stable rules for energy and financial markets, steady revenue generation through bill collection, and profit transfers), most developing countries may have to continue to finance their energy development from domestic savings. In countries without such investment, energy will become a constraint on economic growth, particularly if they are oil and gas importers. In many developing countries, energy imports represent more than half of all imports, imposing a heavy burden on foreign exchange and contributing to indebtedness.

Although energy investment as a share of total investment varies greatly among countries, and at

Conventional energy production and consumption are closely linked to environmental degradation that threatens human health.

different stages of economic development within a country, on average, countries invest 1.0-1.5 percent of GDP in the energy sector. This ratio is expected to remain relatively stable. Based on this assumption, current world-wide investment in the energy supply sector (including equipment and infrastructure) amounts to somewhere between $300 and $400 billion per year.

Energy, the Environment, and Health

The environmental impacts of energy use are not new. For centuries, wood burning has contributed to the deforestation of many areas. Even in the early stages of industrialisation, local air, water, and land pollution reached high levels. What is relatively new is acknowledgement of energy linkages to regional and global environmental problems and the implications of those linkages. Although energy's potential for enhancing human well being is unquestionable, conventional energy production and consumption are closely linked to environmental degradation that threatens human health and quality of life and affects ecological balances and biological diversity.

The environment-energy linkage is illustrated in Table 4, which shows the share of toxic emissions and other pollutants attributable to human energy supply systems. The human disruption index is the ratio of the human-generated flow of a given pollutant (such as sulphur dioxide) to the natural, or baseline, flow. Thus, in the case of sulphur, for example, the index is 2.7, which means that human-generated emissions of 84 million tonnes per year are 2.7 times the natural baseline flow of 31 million tonnes per year. The table indicates that, together with other human activities, energy systems significantly affect the global cycling of important chemicals. Although the index by itself does not demonstrate that these emissions translate into negative impacts, their magnitude provides warning that such impacts could be considerable. Some impacts are already significant.

Just in the last century, during which the world's population more than tripled, human environmental insults grew from local perturbations to global disruptions. The human disruptions of the twentieth century – driven by a more than twenty-fold growth in the use of fossil fuels augmented by a tripling in the use of traditional energy forms such as biomass – have amounted to the emergence of civilisation as an ecological and geo-chemical force of global proportions.

In other words, the accelerating impact of human life is altering the world at the global level.[10] At every level (local, regional, global), the environmental consequences of current patterns of energy generation and use make up a significant fraction of human impacts on the environment.

Poor air quality resulting from solid fuel use for cooking and heating has significant health and environmental impacts at the household, local, regional and global levels. It is associated with increased sickness and premature death. About 1.6 million premature deaths per year – disproportionately women and children – are estimated to occur from exposure to indoor air pollution caused by burning solid fuels in poorly ventilated spaces. Particulate matter (which is both emitted directly and formed in the air as the result of the emissions of gaseous precursors in the form of oxides of sulphur and nitrogen) and hydrocarbons are growing concerns world-wide. They are especially troublesome in many parts of the developing world, where dirtier fuels predominate with little emissions abatement. No safe threshold level for exposure to small particulate matter has been established. The combustion conditions in small cooking fires and stoves are such that a significant amount of unburned hydrocarbon, including some methane, is emitted to the atmosphere. These greenhouse gases are estimated to amount to several percent of the world's total greenhouse gas emissions. Technologies for mitigation/abatement of these pollutants exist, although at a cost.

Fossil fuel combustion is problematic on several levels (although natural gas produces significantly fewer harmful emissions than do oil or coal). The main pollutants emitted in the combustion of fossil fuels are sulphur and nitrogen oxides, carbon monoxide, and suspended particulate matter. Ozone is formed in the troposphere from interactions among hydrocarbons, nitrogen oxides, and sunlight. Energy-related emissions from fossil fuel combustion, including in the transport sector, are major contributors to urban air pollution, which is thought to be responsible for about 800,000

10. In this report, the word insult is used to describe a physical stressor produced by the energy system, such as air pollution. The word impact is used to describe the resulting outcome, such as respiratory disease or forest degradation.

TABLE 4. ENVIRONMENTAL INSULTS DUE TO HUMAN ACTIVITIES, BY SECTOR

Insult	Natural baseline	Human disruption index[a]	Share of human disruption caused by			
			Commercial energy supply	Traditional energy supply	Agriculture	Manufacturing, other
Lead emissions to atmosphere[b]	12,000 t/yr	18	41% (fossil fuel burning, including additives)	Negligible	Negligible	59% (metals processing, manufacturing, refuse burning)
Oil added to oceans	200,000 t/yr	10	44% (petroleum, harvesting, processing, transport)	Negligible	Negligible	56% (disposal of oil wastes, including motor oil changes)
Cadmium emissions to atmosphere	1,400 t/yr	5.4	13% (fossil fuel burning)	5% (burning traditional fuels)	12% (agricultural burning)	70% (metals processing, manufacturing, refuse burning)
Sulfur emissions to atmosphere	31 million t-S/yr	2.7	85% (fossil fuel burning)	0.5% (burning traditional fuels)	1% (agricultural burning)	13% (smelting, refuse burning)
Methane flow to atmosphere	160 million t/yr	3.75[c]	18% (fossil fuel harvesting and processing)	5% (burning traditional fuels)	65% (rice pad-dies, domestic animals, land clearing)	12% (landfills)
Nitrogen fixation (as NO, NH_4)[d]	140 million t-N/yr	1.5	30% (fossil fuel burning)	2% (burning traditional fuels)	67% (fertiliser, agricultural burning)	1% (refuse burning)
Mercury emissions to atmosphere	2,500 t/yr	1.4	20% (fossil fuel burning)	1% (burning traditional fuels)	2% (agricultural burning)	77% (metals processing, manufacturing, refuse burning)
Nitrous oxide flows to atmosphere	33 million t/yr	0.49[c]	12% (fossil fuel burning)	8% (burning traditional fuels)	80% (fertiliser, land clearing aquifer disruption)	Negligible
Particulate emissions to atmosphere	3,100e million t/yr	0.12	35% (fossil fuel burning)	10% (burning traditional fuels)	40% (agricultural burning)	15% (smelting, non-agricultural land clearing, refuse)
Non-methane hydrocarbon emissions to atmosphere	1,000 million t/yr	0.12	35% (fossil fuel processing and burning)	5% (burning traditional fuels)	40% (agricultural burning)	20% (non-agricultural land clearing, refuse burning)
Carbon dioxide flows to atmosphere	150 billion t-C/yr	0.05[f,g]	75% (fossil fuel burning)	3% (net deforestation for fuelwood)	15% (net deforestation for land clearing)	7% (net deforestation for lumber, cement manufacturing)

a. The human disruption index is defined as the ratio of human-generated flow to the natural (baseline) flow. b. Automotive portion of anthropogenic emissions assumed to be 50 percent of global 1993 automotive emissions. c. From IPCC, 2001. d. Calculated from total nitrogen fixation minus that from nitrous oxide. e. Dry mass. f. Although seemingly small, because of the long atmospheric lifetime and other characteristics of carbon dioxide, this slight imbalance in natural flows is causing a 0.4 percent increase per year in the global atmospheric concentration. g. From EIA, 2000.

Source: Updated from J.P. Holdren, "The Transition to Costlier Energy", in L. Schipper and S. Myers, eds., Energy Efficiency and Human Activity: Past Trends, Future Prospects *(Cambridge: Cambridge University Press, 1992).*

deaths annually around the world. Precursors of acid deposition from fuel combustion can be precipitated thousands of kilometres from their point of origin – often crossing national boundaries. The resulting acidification is causing significant damage to natural systems, crops, and human-made structures, and can, over time, alter the composition and function of entire ecosystems. In many regions, acidification has diminished the productivity of forests, fisheries, and farmlands.

Acid deposition is a problem because it causes damage to natural and human-made surfaces with which it comes into contact. If soils contain insufficient alkali to neutralise the acid, damage can be caused to vegetation, particularly sensitive tree species and agricultural crops. Lakes can become acidified, leading to the demise of fish populations. Over time the entire natural structure and function of ecosystems can change. Manufactured materials can be attacked: metal surfaces rust and alkaline materials such as concrete, limestone, and marble erode. In Europe, forest damage

Major changes are required in energy systems development world-wide to meet sustainable development challenges.

has long been attributed to acid deposition; despite emission reductions, the health of European forests continues to deteriorate. However, Asia is the region of greatest concern. Acid deposition is being reported throughout Asia, with many areas receiving levels that exceed the carrying capacity of their soils.

Desertification in the Sahel and elsewhere in sub-Saharan Africa has links to fuel demand. But it has been difficult to separate out the influence of all the relevant factors, including climate change, intensification of grazing, land-use shifts, and fuel harvesting. Nevertheless, as with deforestation, there are some poor areas where harvesting of wood and brush plays an important role.

Fossil fuel combustion produces more carbon dioxide (CO_2) than any other human activity. This is the biggest source of the anthropogenic greenhouse gas emissions that are changing the composition of the atmosphere and could alter the global climate system, including the amount and pattern of rainfall. Stabilising CO_2 at close to the present concentration would require reducing emissions to half of current levels within the next few decades. Instead, CO_2 emissions continue to increase. Current CO_2 emission trends, if not controlled, will lead to more than a doubling of atmospheric concentrations before 2070, relative to pre-industrial levels. Changes have been observed in climate patterns that correspond to scientific projections based on increasing concentrations of greenhouse gases. With increasing evidence that most of the warming observed over the last fifty years is attributable to human activities, concern is growing especially about greenhouse gas emissions. IPCC concludes in its Third Assessment Report that global mean surface temperature has increased by 0.6 degrees Celsius during the last two centuries due to human activities (IPCC, 2001).

By definition, sustainable energy systems must support both human and ecosystem health over the long term. Thus goals on tolerable emissions should be long term and take into account the public's tendency to demand more health and environmental protection as prosperity increases.

Other forms of conventional energy pose problems as well. Large hydropower projects often present environmental problems related to the flooding of large areas; and there is widespread concern about a range of issues associated with nuclear power, particularly its links to nuclear weapons and the sequestering of radioactive waste.

Although the scope of environmental problems related to energy systems may seem overwhelming, numerous strategies could simultaneously benefit the environment (at several levels), the economy, and human well being. For example, replacing solid fuels for cooking with gaseous or liquid fuels could have significant environmental benefits at the local, community, regional, and global scales, with attendant benefits for health and productivity.

Energy Security

Energy security is a term that applies to the availability of energy at all times in various forms, in sufficient quantities, and at affordable prices, without unacceptable or irreversible impact on the environment. These conditions must prevail over the long term if energy is to contribute to sustainable development. Energy security has both a producer and a consumer side to it. In terms of energy resources world-wide to meet energy demand for the foreseeable future there is no energy security problem. However, whether these resources will be available in the marketplace at affordable prices depends on how markets perform, on government taxation and regulation, and on the role of policies such as electrification or subsidies.

Security of supply has taken a higher place on the global agenda recently for a number of reasons: the shift in oil and gas prices from very low levels in the 1990s to higher, more sustained levels today, changes in contracts and other aspects of market reform, deregulation and the establishment of new forms of regulation, protocols to reduce greenhouse gas emissions, and political instability in some main supplier countries (Box 2).

The potential for conflict, sabotage, disruption of production and trade, and reduction in strategic reserves cannot be dismissed. These potential threats lead to sudden transient price increases (price spikes) that cause economic disruptions in many countries and disrupt global economic growth. An increase of $10 per barrel of oil (above relevant average price) can slow the global economy by 0.5 percent annually – a significant amount that points to the need to strengthen global as well as regional and national energy security.

A range of actions can be taken to improve energy security. One important measure is to avoid excessive

BOX 2. SECURITY OF OIL AND GAS SUPPLY

Oil

Dramatic losses of Middle East oil supplies and attendant oil price hikes did not materialise either during or after the Iraq war in 2003. Supply turmoil outside the region in Venezuela, and uncertainty as to Nigeria's capability to keep its oil flowing, increased oil prices in the period leading up to the war and raised concerns about what would happen to the global oil market in the event of war. However, actions by the Organisation of Petroleum Exporting Countries (OPEC) during the pre-war period reassured international markets that there would be no physical shortage. OPEC members, especially Saudi Arabia and Kuwait, committed to using their spare production capacity rather than force consuming countries to tap strategic oil reserves. Moreover, the fact that cumulative OPEC production has been well in excess of the prevailing production quotas also had a calming effect on prices. Drawing on lessons learned in the first Gulf war in 1991, major oil market stakeholders in both the private sector and government knew the importance of early information and transparent information flow to avoid panic buying and logistical disruption.

In essence, markets worked and oil supplies remained secure throughout the Iraq war. For the time being, a system of spare production capacity maintained by core producers paired with the potential for strategic oil stock releases appears to be a most effective remedy in the event of a physical oil supply shortage. While this certainly is reassuring for those concerned about oil and energy security, there is no room for complacency. The war's impacts on oil infrastructures were largely confined to Iraq and did not spread into the rest of the Middle East producing region. The positive experience gained in two wars must not eclipse the fact that sizeable energy import dependence from a single region or oligopolistic supplier will always remain a fundamental supply security risk. As fewer countries continue to have the capacity to export conventional oil, and as long as global demand for oil continues to rise, the scope for chronic conventional oil supply disruption will grow.

Natural Gas

Gas is generally the most expensive fuel on a delivered kWh basis; as a result, growth in gas consumption will be primarily for mid/peak load use. Given this gas use at the margin, spot price signals are of fundamental importance.

In North America, domestic gas supply is declining, creating a growing need for liquid natural gas (LNG) imports. In Western Europe, domestic gas supply is nearly at its peak, and imports by pipeline are not going to grow much since fields in the Siberian region are all in decline and production in other areas of the former Soviet Union are problematic. Long-term commitments by buyers are needed to finance new infrastructure. All these factors suggest that LNG prices will increase in the future. Due to growing markets in North America and Western Europe, the developing countries face penalties if they do not secure enough supply for the needs of their internal markets. High import dependency will continue to be a concern for many countries.

dependence on fossil fuel imports. This involves diversifying supply – both geographically and among various primary energy sources – as well as increasing end-use efficiency and encouraging greater reliance on local, including renewable, resources. Promoting renewable energy will have other positive externalities such as job creation and pollution reduction, provided that these do not have disproportionate costs or waste scarce resources.

Another important measure is fostering greater political stability through international co-operation and long-term agreements among energy-importing countries and between importing and exporting countries. Examples might include wider adoption – and more effective implementation – of the Energy Charter Treaty[11] as well as increased sharing of infrastructure for transporting natural gas. The geopolitical problems involved in building such projects, particularly in Central Asia, should not be overlooked.

Additional measures to enhance energy security include: a) encouraging technology transfers to developing countries (e.g., through joint ventures and public-private partnerships) so they can develop local resources and improve energy production and efficiencies; b) increasing national and regional strategic reserves of crude oil and oil products through increased investment and advanced exploration technologies; and c) promoting sustainable international markets for biofuels (e.g., ethanol) and international trade between producers and consumers of such fuels.

Nuclear power contributes both to the diversity of supply and to supply security since its fuel requirements are small. However, public concern about economic cost, reactor safety, radioactive waste transport and disposal, and nuclear weapons proliferation raises important political issues and has curbed the growth of nuclear energy in many countries. A nuclear accident anywhere in the world or a proliferation incident linked to nuclear power would further reduce support for nuclear power programmes. However, if these concerns can be dealt with in ways that are widely accepted, nuclear energy could contribute significantly to electricity generation in many parts of the world.

One feature enhancing energy security is the growing interdependence between industrialised countries and oil exporters. Oil producers recognise that oil is a traded commodity; they are as anxious about security of demand as oil importers are about security of supply. There is a possibility, however remote, that large military action or a terrorist attack could cause a serious interruption in the flow of oil or natural gas/liquid natural gas (by disrupting sea-lanes, for instance). Building emergency oil stocks can marginally deal with such prospects, but

11. The Energy Charter Treaty, together with a protocol on energy efficiency and related environmental aspects, entered into force in 1998. About fifty countries, including the members of the European Union and the Commonwealth of Independent States, Australia, and Japan, have signed it.

such arrangements are expensive, particularly for developing countries. The new International Energy Forum based in Riyadh is an attempt to enhance the producer-consumer dialogue on oil and natural gas.

There is an absolute link between meeting the needs of economic growth, creating the conditions for an acceptable quality of life, and ensuring sustainable development while protecting the environment. Energy security is a delicate balance among these diverse requirements and there is no question that a least-cost mix of efficient use with more diverse, dispersed resources can make the energy system more resilient and sustainable. ■