CHAPTER 4

energy security

Hisham Khatib (Jordan)

LEAD AUTHORS: Alexander Barnes (France), Isam Chalabi (Iraq), H. Steeg (Germany), K. Yokobori (Japan, on behalf of Asia-Pacific Economic Cooperation), and the Planning Department, Organisation of Arab Oil Producing Countries (Kuwait)

The ideas expressed in the chapter are entirely the responsibility of the Convening Lead Author.

ABSTRACT Energy security—the continuous availability of energy in varied forms, in sufficient quantities, and at reasonable prices—has many aspects. It means limited vulnerability to transient or longer disruptions of imported supplies. It also means the availability of local and imported resources to meet, over time and at reasonable prices, the growing demand for energy. Environmental challenges, liberalisation and deregulation, and the growing dominance of market forces all have profound implications for energy security. These forces have introduced new elements into energy security, affecting the traditionally vital role of government.

In the past, and especially since the early 1970s, energy security has been narrowly viewed as reduced dependence on oil consumption and imports, particularly in OECD and other major oil-importing countries. But changes in oil and other energy markets have altered that view. Suppliers have increased, as have proven reserves and stocks, and prices have become flexible and transparent, dictated by market forces rather than by cartel arrangements. Global tensions as well as regional conflicts are lessening, and trade is flourishing and becoming freer. Suppliers have not imposed any oil sanctions since the early 1980s, nor have there been any real shortages anywhere in the world. Instead, the United Nations and other actors have applied sanctions to some oil suppliers, but without affecting world oil trade or creating shortages. All this points to the present availability of abundant oil supplies at all times, an availability that has been greatly enhanced thanks in large part to technological advances. Moreover, in today's market environment energy security is a shared issue for importing and exporting countries.

Energy security can be ensured through local adequacy—abundant and varied forms of indigenous energy resources. But for countries that face local shortages, as most do, energy security can be enhanced through:

- The ability, of the state or of market players, to draw on foreign energy resources and products that can be freely imported through ports or other transport channels and through cross-boundary energy grids (pipelines and electricity networks). This is increasingly aided by energy treaties and charters and by investment and trade agreements.
- Adequate national (or regional) strategic reserves to address any transient interruption, shortages, or unpredictably high demand.
- Technological and financial resources and know-how to develop indigenous renewable energy sources and domestic power generating facilities to meet part of local energy requirements.
- Adequate attention to environmental challenges.
- Diversification of import sources and types of fuels.

Energy security can also be greatly enhanced by energy conservation and efficiency measures, because reducing energy intensity will reduce the dependence of the economy on energy consumption and imports.

But while all this is very encouraging, new threats to energy security have appeared in recent years. Regional shortages are becoming more acute, and the possibility of insecurity of supplies—due to disruption of trade and reduction in strategic reserves, as a result of conflicts or sabotage—still exists, although it is decreasing. All this points to a need to strengthen global as well as regional and national energy security. This chapter discusses some means and instruments for doing so. ■

Energy insecurity and shortages handicap productive activities and undermine consumer welfare.

The world has generally seen considerable development and progress in the past 50 years. Living standards have improved, people have become healthier and longer-lived, and science and technology have considerably enhanced human welfare. No doubt the availability of abundant and cheap sources of energy, mainly in the form of crude oil from the Middle East, contributed to these achievements. Adequate global energy supplies, for the world as a whole as well as for individual countries, are essential for sustainable development, proper functioning of the economy, and human well-being. Thus the continuous availability of energy—in the quantities and forms required by the economy and society—must be ensured and secured.

Energy security—the continuous availability of energy in varied forms, in sufficient quantities, and at reasonable prices—has several aspects. It means limited vulnerability to transient or longer disruptions of imported supplies. It also means the availability of local and imported resources to meet growing demand over time and at reasonable prices.

Beginning in the early 1970s energy security was narrowly viewed as reduced dependence on oil consumption and imports, particularly in OECD and other major oil-importing countries. Since that time considerable changes in oil and other energy markets have altered the picture. Suppliers have increased, as have proven reserves and stocks, and prices have become flexible and transparent, dictated by market forces rather than by cartel arrangements. Global tensions and regional conflicts are lessening, and trade is flourishing and becoming freer. Suppliers have not imposed any oil sanctions since the early 1980s, nor have there been any real shortages anywhere in the world. Instead, the United Nations and other actors have applied sanctions to some oil suppliers, but without affecting world oil trade or creating shortages.

All this points to the present abundance of oil supplies. Moreover, in today's market environment energy security is a shared issue for importing and exporting countries. As much as importing countries are anxious to ensure security by having sustainable sources, exporting countries are anxious to export to ensure sustainable income (Mitchell, 1997).

However, although all these developments are very encouraging, they are no cause for complacency. New threats to energy security have emerged in recent years. Regional shortages are becoming more acute, and the possibility of insecurity of supplies—due to disruption of trade and reduction in strategic reserves, as a result of conflicts or sabotage—persists, although it is decreasing. These situations point to a need to strengthen global as well as regional and national energy security (some means for doing this are discussed later in the chapter). There is also a need for a strong plea, under the auspices of the World Trade Organization (WTO), to refrain from restrictions on trade in energy products on grounds of competition or differences in environmental or labour standards.

Environmental challenges to sustainable development are gaining momentum and have profound implications for energy security, as do the current trends of liberalisation, deregulation, and the growing dominance of market forces. These forces have introduced new elements into energy security, affecting the traditionally vital role of government, as described below. They also have consequences for medium-size companies and individual consumers, who may be tempted by cheap competitive prices and lack of information to sacrifice, sometimes temporarily, supply security.

Energy has always been important to humanity. But its importance is increasing each year. Interruptions of energy supply—even if brief—can cause serious financial, economic, and social losses. Some energy products and carriers have become absolutely essential for modern life and business. Interruption of electricity supply can cause major financial losses and create havoc in cities and urban centres. The absolute security of the energy supply, particularly electricity, is therefore critical. With the widespread use of computers and other voltage- and frequency-sensitive electronic equipment, the quality of supply has also become vital. In the electricity supply industry, a significant share of investment goes into reserve generating plants, standby equipment, and other redundant facilities needed to protect the continuity and quality of supply.

Energy insecurity and shortages affect countries in two ways: they handicap productive activities, and they undermine consumer welfare. Energy insecurity discourages investors by threatening production and increasing costs. Shortages in electricity supplies (as in many developing countries) require more investment for on-site electricity production or standby supplies. For small investors, the cost of operation is increased, since electricity from private small-scale generation is more expensive than public national supplies. Electricity interruptions at home cause consumers great inconvenience, frustration, and loss of productivity, sometimes threatening their well-being.

For any economy, an unreliable energy supply results in both short- and long-term costs. The costs are measured in terms of loss of welfare and production, and the adjustments that consumers (such as firms) facing unreliable fuel and electric power supplies undertake to mitigate their losses. Interruptions in supply may trigger loss of production, costs related to product spoilage, and damage to equipment. The extent of these direct economic costs depends on a host of factors, such as advance notification, duration of the interruption, and timing of the interruption, which relates to the time of day or season and to the prevailing market conditions and demand for the firm's output. These direct costs can be very high. In addition, the economy is affected indirectly because of the secondary costs that arise from the interdependence between one firm's output and another firm's input.

New dimensions and challenges to energy security

Energy security needs to be investigated at several levels: globally, to ensure adequacy of resources; regionally, to ensure that networking

Reducing energy intensity will reduce the dependence of the economy on energy consumption and imports.

and trade can take place; at the country level, to ensure national security of supply; and at the consumer level, to ensure that consumer demand can be satisfied. At the country level, energy security is based on the availability of all energy consumption requirements at all times from indigenous sources or imports and from stocks. Normally in most countries, this is a state responsibility. However, markets in some OECD countries are increasingly shouldering part of this responsibility. To ensure energy security, projections, plans, and supply arrangements should look beyond short-term requirements to medium- and long-term demand as well.

With the increasing deregulation and competition among private and independent suppliers, supply security at the consumer level can become more vulnerable and correspondingly more important in some cases. Consumer demand for energy services can be met by different suppliers competing to deliver different forms of energy at different prices, while the consumer remains unaware of the degree of supply security.

As explained above, environmental challenges, deregulation, and market forces have introduced new players to the energy security scene. This chapter considers energy security at the national (and regional) level as well as consumer security in terms of energy services. In most countries these two levels of security are one and the same. But in some OECD countries, with markets and competition emerging at the consumer level, the two may diverge. The chapter also covers the geopolitical aspects of energy security as well as the limitations of the resource base and other factors that may affect long-term energy security.

Of all energy sources, crude oil and its products are the most versatile, capable of meeting every requirement for energy use and services, particularly in transport. The other fossil fuels, coal and natural gas, are well suited for electricity production and such stationary uses as generation of heat and steam. Coal, increasingly used for electricity production, requires relatively expensive clean technologies, and treatment for liquefaction and gasification to make it more versatile. Natural gas also requires expensive infrastructure, and special treatment to make it useful for transport. Hydropower, newer renewable resources such as wind and photovoltaics, and nuclear energy have limited use beyond electricity production.

Given the versatility of crude oil and its products and the limitations of other energy sources, energy security depends more than anything else on the availability of crude oil in the required amounts (by ship or pipeline) to any importing country in the world. Thus, although energy security has to be interpreted more broadly than in the past, the uninterrupted supply of crude oil in the required amounts and at reasonable prices will continue to be the most important determinant of energy security. Uninterrupted supply—of oil and other forms of energy—includes uninterrupted transit through third countries. As the chapter details later, work is under way, through the Energy Charter Treaty, to improve security for exporters and importers and to promote a favourable climate for investments in upgrading and building new and diversified pipeline routes.

Security of electric power supply

Chronic energy shortages and poor security of the electric power supply trigger long-term adjustments.

If firms expect shortages and unreliable service to persist, they will respond in one or more ways. The most common long-term adjustment by commercial consumers and small industrial firms is to install back-up diesel generator sets. It has been estimated that in many developing countries such standby generation on customer premises accounts for 20 percent or more of the total installed generating capacity (USAID, 1988).

The shortages and inadequate maintenance of the grid also add to poor security. In some developing countries half the public electricity supply is inoperable at any given time. Many manufacturing firms have had to purchase their own generators to meet their demand for electricity. In Nigeria about 92 percent of firms surveyed in the mid-1990s had their own generators. This purchase added to their fixed costs, raised production costs, and tended to discourage new investments. For small firms, the investment in generating capacity represented almost a quarter of their total investment, and for large firms, a tenth (ADB, 1999). Moreover, in many developing countries the electric power system losses (technical and non-technical) are very high, exceeding a quarter of generation in some and as much as half in a few.

Shortages of electric power and supply interruptions are not uncommon, particularly in many developing countries. They occur for two main reasons:

- System inadequacy—shortfalls of delivered electricity under even the best conditions in the electric power system. Such shortfalls, most common in developing countries, usually occur because of an inadequate number of generating facilities capable of meeting peak demand and limitations in the transmission and distribution system, particularly to rural areas.
- Supply insecurity—unreliability of supply due to non-availability of generating plants or breakdowns in the transmission and distribution system. This can occur in varying degrees in any power system in the world.

To ensure system adequacy—the ability of a power system to meet demand and deliver adequate electricity to consumers—requires investment. Most investments in electric power security are meant to reduce the likelihood of shortages and maintain and improve reliability. Most shortages occur as a result of growth in demand, which necessitates expanding generation capacity and strengthening networks. But even with large investments, interruptions are inevitable. And the costs of improving continuity of supply can become very high once a certain level of reliability has been reached.

The function of the electric power system is to provide electricity as economically as possible and with an acceptable degree of security

and quality. The economics of electric power security (reliability) involve striking a reasonable balance between cost and quality of service. This balance varies from country to country, and from one category of consumers to another.

To improve supply security, countries invest in redundant facilities. These investments, in reserve generating capacity and other network facilities, normally amount to at least a third of the investments by the electricity supply industry. Low-income developing countries cannot afford such huge investments, leading to supply insecurity. Thus in many developing countries, electricity supplies are enhanced by standby plants on consumer premises. Many industries and commercial outlets have to spend heavily on in-house generation or standby plants to attain a reasonable standard of continuity. This greatly increases the cost of attaining supply security and places an added burden on the limited economic resources of these countries.

Supply interruptions occur not only because of shortages in generating plants or limitations in the grid. They are also attributed to inadequate maintenance due to lack of skilled staff or shortage of spare parts. Attaining a reasonable standard of performance in developing countries' public systems is essential not only to improve electricity supply security but also to limit the wasted resources in standby plants and reserve generating capacity. This can be achieved through proper planning of the system and by investing in training and maintenance rather than only in system expansion.

The cost of insecurity of the electricity system in developing countries varies by country depending on the extent of electrification and quality of the supply. However, in industrialised countries the costs of supply insecurity for non-deferrable economic activities are huge. In the United States it was estimated that these costs might exceed $5 billion a year (Newton-Evans Research Company, 1998). Most of these costs are borne by industrial and commercial consumers (box 4.1).

Routes to enhanced energy security

Energy security can be ensured by local adequacy—abundant and varied forms of indigenous energy resources. In the case of local shortages, which occur in most countries, energy security can be enhanced through:

- The ability, of the state or of market players, to draw on foreign energy resources and products that can be freely imported through ports or other transport channels and through cross-boundary energy grids (pipelines and electricity networks).
- Adequate national (or regional) strategic reserves to address any transient interruption, shortages, or unpredictable surge in demand.
- Technological and financial resources and know-how to develop indigenous renewable sources and power generating facilities to meet part of local energy requirements.
- Adequate attention to environmental challenges.

Energy security can also be enhanced through energy conservation and efficiency measures. Reducing energy intensity will reduce the dependence of the economy on energy consumption and imports.

To achieve energy security requires first of all ensuring global energy adequacy—the existence of enough energy resources, or other prospects, to meet long-term world energy needs.

Energy adequacy

Although energy resources are examined in detail elsewhere in this report (see chapter 5), a quick review is provided here because energy security depends, to a great extent, on the availability of an adequate resource base. The resource base is the sum of reserves and resources. Reserves are occurrences (of all types and forms of hydrocarbon deposits, natural uranium, and thorium) that are known and economically recoverable with present technologies. Resources are less certain, are not economically recoverable with present technologies, or are both. In the future, with advances in technology and geophysics, many of today's resources are likely to become reserves (McKelvey, 1972).

Most of the world's future energy requirements, at least until the middle of the 21st century, will have to be met by fossil fuels (figure 4.1). Many attempts have been made to assess the global fossil fuel resource base. Table 4.1 shows the results of two.

BOX 4.1 VALUING THE COST OF ELECTRICITY SUPPLY SECURITY

The cost of electricity to a consumer—the consumer's valuation of the electricity supply (ignoring consumer surplus)—equals payments for electricity consumed plus the economic (social) cost of interruptions.

Supply insecurity causes disutility and inconvenience, in varying degrees and in different ways, to different classes of consumers—domestic, commercial, and industrial. The costs and losses (L) for the average consumer from supply interruptions are a function of the following:

- Dependence of the consumer on the supply *(C)*.
- Duration of the interruptions *(D)*.
- Frequency of their occurrence during the year *(F)*.
- Time of day in which they occur *(T)*.

That is, $L = C\ (D^d \times F^f, T^t)$, where *d, f,* and *t* are constants that vary from one consumer category to another.

The table shows estimates of the annual cost of electricity supply interruptions for the U.S. economy.

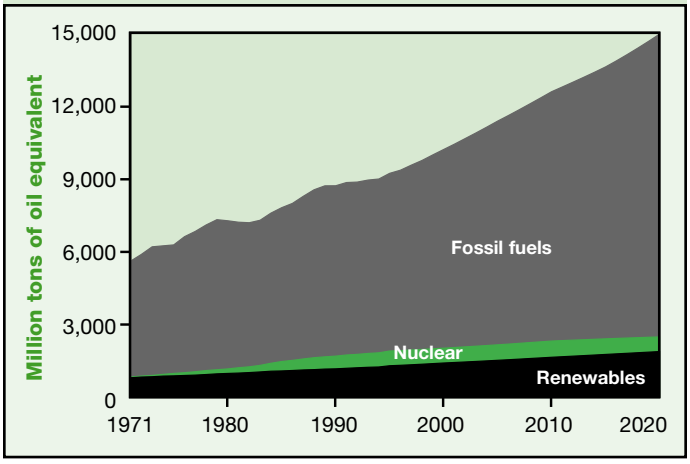
Economic cost of electricity supply interruptions for non-deferrable economic activities the United States, 1997

Consumer class and average duration of interruption	Cost to consumer per outage (U.S. dollars)	Cost to consumer per lengthy outage (U.S. dollars)	Estimated total annual losses (billions of U.S. dollars)
Residential (20 minutes)	0–20	50–250	0.9–2.7
Commercial (10 minutes)	25–500	5–20 (per minute)	2.9–11.7
Industrial (less than 30 seconds)	200–500 (small plant) 1,000–10,000 (large plant)	5,000–50,000 (per 8-hour day)	1.1–13.5

Note: Assumes nine outages a year for each class of consumer.

Source: Newton-Evans Research Company, 1998.

FIGURE 4.1. SHARE OF FUELS IN GLOBAL ENERGY SUPPLY, 1971–2020



Source: IEA, 1998.

In 1998 world consumption of primary energy totalled almost 355 exajoules, or 8,460 million tonnes of oil equivalent (Mtoe)—7,630 Mtoe of fossil fuels, 620 Mtoe of nuclear energy, and 210 Mtoe of hydropower. To this should be added around 47 exajoules (1,120 Mtoe) of biomass and other renewables, for a total of 402 exajoules (9,580 Mtoe). The huge resource base of fossil and nuclear fuels will be adequate to meet such global requirements for decades to come.

Crude oil

Proven oil reserves have increased steadily over the past 20 years, mainly because oil companies have expanded their estimates of the reserves in already discovered fields. This optimism stems from better knowledge of the fields, increased productivity, and advances in technology. New technologies have led to more accurate estimates of reserves through better seismic (three- and four-dimensional) exploration, have improved drilling techniques (such as horizontal and offshore drilling), and have increased recovery factors—the share of oil that can be recovered—from 30 percent to 40–50 percent (Campbell and Laherrere, 1998).

Huge amounts of untapped unconventional oil also exist, augmenting conventional oil reserves. Some 1.2 trillion barrels of heavy oil are found in the Orinoco oil belt in Venezuela. And the tar sands of Canada and oil shale deposits of the Russian Federation may contain 300 billion barrels of oil.

The U.S. Geological Survey assessed ultimate oil and gas reserves at the beginning of 1993 (IEA 1998; WEC, 1998). The results, which tally with the World Energy Council (WEC) and International Energy Agency (IEA) figures (see table 4.1), point to ultimate conventional oil reserves of 2,300 billion barrels, with cumulative production until 1993 amounting to 700 billion barrels and unidentified reserves to 470 billion. No shortage of conventional liquid fuels is foreseen before 2020. Any deficiencies after that can be met by the ample reserves of unconventional oil.

Natural gas

The U.S. Geological Survey also assessed ultimate natural gas reserves in 1993 (Masters, 1994). It estimated ultimate reserves at 11,448 trillion cubic feet (11,214 exajoules, or 267 gigatonnes of oil equivalent [Gtoe]), with cumulative production until 1993 amounting to 1,750 trillion cubic feet (1,722 exajoules, or 41 Gtoe). Cumulative world gas production through the end of 1995 was only 17.1 percent of the U.S. Geological Survey's estimate of conventional gas reserves.

Natural gas consumption is projected to grow 2.6 percent a year, mostly as a result of growth in electricity generation in non-OECD countries. Despite this growth, cumulative production is expected to be no more than 41 percent of the U.S. Geological Survey's estimate of conventional gas reserves by 2020. This points to a resource base large enough to serve global requirements for natural gas well into the second half of the 21st century.

TABLE 4.1. GLOBAL ENERGY RESOURCE BASE (EXAJOULES EXCEPT WHERE OTHERWISE INDICATED)

Term	World Energy Council estimates		Institute for Applied Systems Analysis estimates			Consumption
	Proven reserves	Ultimately recoverable	Reserves	Resources	Resource base	1998
Conventional oil	6,300 (150)	8,400 (200)	6,300 (150)	6,090 (145)	12,390 (295)	142.8 (3.4)
Unconventional oil	—	23,100 (550)	8,190 (195)	13,944 (332)	22,050 (525)	n.a.
Conventional gas	5,586 (133)	9,240 (220)	5,922 (141)	11,718 (279)	17,640 (420)	85 (2.0)
Unconventional gas	—	—	8,064 (192)	10,836 (258)	18,900 (450)	n.a.
Coal and lignite	18,060 (430)	142,800 (3,400)	25,452 (606)	117,348 (2,794)	142,800 (3,400)	93 (2.2)
Uranium	3.4 x 10^9 tonnes	17 x 10^9 tonnes	(57)	(203)	(260)	64,000 tonnes

— Not available; n.a. Not applicable. *Source: WEC, 1998; IIASA, 1998.*
Note: Numbers in parentheses are in gigatonnes of oil equivalent. For definitions of conventional and unconventional resources, see chapter 5.
a. Because of uncertainties about the method of conversion, quantities of uranium have been left in the units reported by the sources.

Techniques for gasification, fermentation, and anaerobic digestion are all increasing the potential of biomass as a sustainable energy source.

Coal

Coal is the world's most abundant fossil fuel, with reserves estimated at almost 1,000 billion tonnes, equivalent to 27,300 exajoules, or 650,000 Mtoe (WEC, 1998). At the present rate of production, these reserves should last for more than 220 years. Thus the resource base of coal is much larger than that of oil and gas. In addition, coal reserves are more evenly distributed across the world. And coal is cheap. Efforts are being made to reduce production costs and to apply clean coal technologies to reduce the environmental impact.

Coal demand is forecast to grow at a rate slightly higher than global energy growth. Most of this growth will be for power generation in non-OECD countries, mostly in Asia. Although trade in coal is still low, it is likely to increase slowly over time. Long-term trends in direct coal utilisation are difficult to predict because of the potential impact of climate change policies. Coal gasification and liquefaction will augment global oil and gas resources in the future.

Nuclear energy

Although nuclear energy is sometimes grouped with fossil fuels, it relies on a different resource base. In 1998 nuclear energy production amounted to 2,350 terawatt-hours of electricity, replacing 620 Mtoe of other fuels. Uranium requirements amounted to 63,700 tonnes in 1997, against reasonably assured resources (reserves) of 3.4 million tonnes. Ultimately recoverable reserves amount to almost 17 million tonnes. Considering the relative stagnation in the growth of nuclear power, the enormous occurrences of low-grade uranium, and the prospects for recycling nuclear fuels, such reserves will suffice for many decades.

Renewables

Renewable energy sources—especially hydroelectric power, biomass, wind power, and geothermal energy—account for a growing share of world energy consumption. Today hydropower and biomass together contribute around 15 percent.

Hydroelectric power contributes around 2,500 terawatt-hours of electricity a year, slightly more than nuclear power does. It replaces almost 675 Mtoe of fuels a year, although its direct contribution to primary energy consumption is only a third of this. But it has still more potential. Technically exploitable hydro resources could potentially produce more than 14,000 terawatt-hours of electricity a year, equivalent to the world's total electricity requirements in 1998 (WEC, 1998). For environmental and economic reasons, however, most of these resources will not be exploited.

Still, hydropower will continue to develop. Hydropower is the most important among renewable energy sources. It is a clean, cheap source of energy, requiring only minimal running costs and with a conversion efficiency of almost 100 percent. Thus its annual growth could exceed the growth of global energy demand, slightly improving hydropower's modest contribution towards meeting world requirements.

Renewable energy sources other than hydro are substantial. These take the form mainly of biomass. Traditional biomass includes fuelwood—the main source of biomass energy—dung, and crop and forest residues. Lack of statistics makes it difficult to accurately estimate the contribution of renewables to the world's primary energy consumption. But it is estimated that the world consumed around 1.20 Gtoe in 1998. About two-thirds of this was from fuelwood, and the remainder from crop residues and dung. Much of this contribution is sustainable from a supply standpoint. But the resulting energy services could be substantially increased by improving conversion efficiencies, which are typically very low.

The contribution of biomass to world energy consumption is expected to increase slightly. It is mainly used as an energy source in developing countries. While energy demand in these countries is steadily increasing, some of the demand is being met by switching from traditional to commercial energy sources.

Biomass energy technology is rapidly advancing. Besides direct combustion, techniques for gasification, fermentation, and anaerobic digestion are all increasing the potential of biomass as a sustainable energy source. The viability of wind energy is increasing as well. Some 2,100 megawatts of new capacity was commissioned in 1998, pushing global wind generating capacity to 9,600 megawatts. Wind power accounted for an estimated 21 terawatt-hours of electricity production in 1999. While that still amounts to only 0.15 percent of global electricity production, the competitiveness of wind power is improving and its growth potential is substantial. Use of geothermal energy for electricity generation is also increasing, with a present generating capacity of more than 8,300 megawatts.

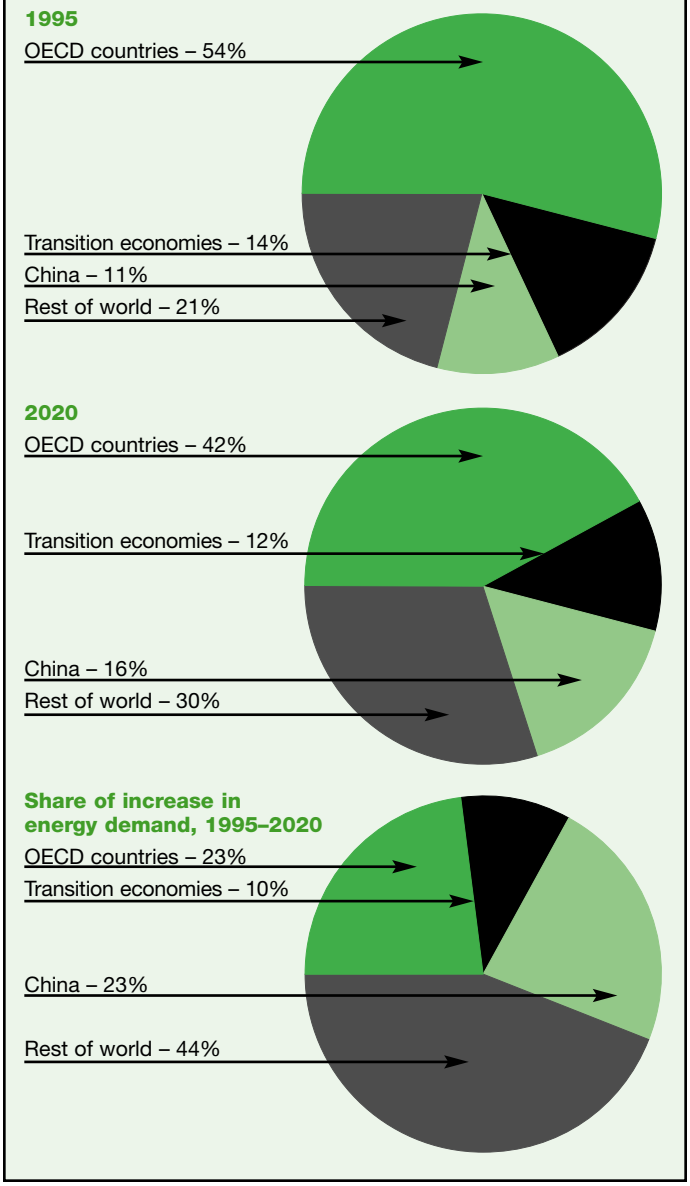
The resource outlook

To summarise, no serious global shortage of energy resources is likely during at least the first half of the 21st century. Reserves of traditional commercial fuels—oil, gas, and coal—will suffice for decades to come. When conventional oil resources are depleted, the huge unconventional oil and gas reserves will be tapped as new extraction and clean generating technologies mature. Coal reserves are also huge: the resource base is more than twice that of conventional and unconventional oil and gas. Clean technologies for coal will allow greater exploitation of this huge resource base, mainly in electricity production, but also through conversion into oil and gas, minimising environmentally harmful emissions.

The uranium resource base is also immense, and it is unlikely, at least in the short term, to be tapped in increasing amounts. The ultimately recoverable uranium reserves will easily meet any nuclear power requirements during this century.

The renewable resource base is also promising. Only part of the global hydro potential has been tapped. Hydropower plants will continue to be built as demand for electricity grows and the economics of long-distance, extra-high-voltage transmission improve. Biomass

FIGURE 4.2. SHIFTING CONCENTRATION OF WORLD ENERGY DEMAND, 1995–2020



Source: IEA, 1998.

has substantial potential and will continue to be used not only as a traditional fuel but also in increasingly sophisticated ways, through thermochemical and biochemical applications. New renewable sources, particularly wind power, will gradually increase the contribution of renewables to global energy supplies as the economies and technologies of these environmentally attractive sources continue to improve.

In short, the world's energy supplies offer good prospects for energy security in the 21st century. The fossil fuel reserves amount to 1,300 Gtoe and the fossil fuel resource base to around 5,000 Gtoe (see table 4.1), amounts sufficient to cover global requirements throughout this century, even with a high-growth scenario. That does not mean there will be no temporary or structural energy shortages, but as long as the energy resources are being explored and exploited, these shortages will not be due to resource inadequacy.

Supply security

Energy resources are not evenly distributed across the world. Oil in particular, and natural gas to a lesser extent, are concentrated in a few regions. The concentration of oil reserves in the Persian Gulf region has always caused concerns about continuity of supply. Most countries, particularly OECD countries, experienced oil shortages and high prices in the 1970s and early 1980s, with physical disruption in supply leading to economic disruption. Energy importers are anxious not to repeat such experiences.

The oil supply situation has improved significantly since then. OECD countries' share of the energy market is decreasing, while that of developing countries is increasing (figure 4.2). This adds to the security of oil supplies because many developing countries are oil producers or have supply arrangements with producers. OECD countries, which accounted for 70 percent of the energy market in the 1970s, will see their market share fall to less than half by 2010. Technological advance has allowed the discovery and development of new energy reserves and reduced the cost of supplies. It has also helped increase efficiency in energy use, loosening the historically tight link between economic development and energy consumption.

Another major favourable development is the reduction in the sources of conflict that can affect global energy security. The cold war is over, and stability in the Middle East, although still precarious, is improving, with the Arab-Israeli conflict moving towards resolution.

However, some other global developments present both opportunities and new challenges to the energy sector. The policy emphasis on environmentally sustainable development, particularly in OECD countries, has important long-term implications for energy security. And the market liberalisation taking place in most industrialised countries has reduced the state's role in energy security—and increased that of consumers.

Energy security is also important for energy producers and exporters. History shows that oil supply disruptions have negative effects on oil-exporting economies. As consumers in importing economies shift away from oil, the lower demand causes severe economic damage to the exporters. In addition, many oil-exporting countries have recently obtained stakes in downstream operations in importing countries. This involvement in OECD economies will contribute towards energy security, as supply disruptions could mean a loss of business opportunities for both oil exporters and importers.

Causes of supply disruption are not limited to disturbances in production facilities. Disruptions can also occur in the long supply chains, such as serious tanker accidents in the most heavily travelled zones—the Strait of Malacca, for example. Vulnerability to disruption may grow as energy supplies are increasingly delivered through grids (gas pipelines and extra-high-voltage transmission networks). Some of these cross national boundaries and are at least theoretically

vulnerable to damage through sabotage and other political disturbances. Terrorist actions could damage liquefied natural gas (LNG) conversion and receiving stations and tankers. But such possibilities are remote. Most energy supplies are delivered under long-term contracts that commit governments to ensuring safe transit and security.

Despite the favourable developments in the energy market, energy security continues to concern planners and strategists in most importing countries. Long-term energy security can be enhanced in several ways:

- Increasing energy independence by fostering and developing local resources (although some may not be economical). Supply security should not be measured solely by energy independence, however. An intelligent supply policy that includes external energy sources can offset many of the drawbacks of dependence and be more economical than a policy that precludes energy imports.
- Diversifying sources of supply and forms of energy used (box 4.2).
- Encouraging international cooperation and agreements among energy-importing countries and between consumer and supplier countries, whether between governments or between companies.
- Investing in and transferring technology to developing countries. Enabling developing countries to develop more energy supplies will enhance the availability of global supplies. Helping these countries increase the efficiency of energy use and improve environmental management will have a similar effect.
- Enhancing and increasing national and regional strategic reserves of crude oil and its products.

> No serious global shortage of energy resources is likely during at least the first half of the 21st century.

Of all the forms of energy, crude oil and its products are still the most important for energy security, because of oil's versatility and because it is the optimal form of energy for the transport sector. Natural gas, because of its affordability and cleanliness, is gaining in importance. Nuclear energy, despite its past promise, faces many difficulties. The security of all these energy forms, as well as coal, is discussed below. Energy intensity is also discussed, because improvements in this area could yield a wider range of benefits for energy security than could providing new sources of energy.

Security of crude oil supply

Over the past 20 years many changes in the oil market have improved the overall security of the energy market. The world economy has become less dependent on oil, as most regions have diversified their energy sources. Oil constituted almost 46 percent of world commercial energy sources in 1973, compared with 40 percent now. There has also been diversification of supply. In the early 1970s the Organization of Petroleum Exporting Countries (OPEC) accounted for more than half the world's oil; today it provides only 42 percent. The world now has 80 oil-producing countries (although very few have the surge capacity needed in emergencies). The oil markets

BOX 4.2. FRANCE'S EFFORTS TO ENHANCE ENERGY SECURITY

France has few energy resources and yet is highly industrialised and thus heavily dependent on adequate and reliable energy supplies. Its total energy consumption is estimated at 240 million tonnes of oil equivalent (Mtoe) a year, while domestic primary energy production of oil, gas, and coal amounts to only 8 Mtoe and is declining.

France, which produced half its total energy requirements in the early 1960s, saw its energy self-sufficiency decline sharply by the 1970s, when it produced only 22 percent of its requirements. But through intensive effort and ambitious energy planning, France reversed this trend of increasing dependence on imported energy. Thanks to its advanced technological skills, France was able to undertake an ambitious nuclear energy programme that helped it regain its 50 percent energy self-sufficiency in the late 1980s and to maintain it since.

To enhance its energy security, France pursued the following actions, which take into account its high standard of living, extensive industrialisation, and limited indigenous sources of primary energy:

- Diversification of energy sources and structure of energy use. France significantly reduced its dependence on imported oil from the Middle East, increased its dependence on gas, mainly from European and Algerian sources, and considerably increased its dependence on domestic electricity produced by nuclear power stations (see the table below).
- Participation in regional cooperation and joint actions, including the International Energy Agency and the Energy Charter Treaty.
- Reduction and rationalisation of demand by improving energy efficiency and encouraging conservation through pricing and taxation, particularly of petroleum products.
- Regional interconnection of gas and electricity networks, helping to mitigate temporary problems in the supply chain.
- Substitution of natural gas and nuclear electricity for petroleum products wherever possible.

By focusing on nuclear energy, France no doubt enhanced its energy security. But it also introduced a new vulnerability into its system. Nuclear power is a viable link in the energy chain as long as it is safe and publicly accepted. With the accidents at U.S., Russian, and Japanese nuclear plants and the growing strength of anti-nuclear parties in Europe, there is no guarantee that it will remain publicly accepted over the long term.

Energy supply structure in France, 1973 and 1997 (percent)

Cost	1973	1997
Primary energy		
Coal	14.5	5.6
Oil	66.3	39.7
Gas	7.0	13.1
Primary electricity[a]	7.0	36.6
Renewables[b]	5.2	5.0
Final energy		
Coal	11.0	4.0
Oil	56.4	37.1
Gas	5.5	13.9
Electricity	20.9	39.1
Renewables[b]	6.2	5.9

a. Most primary electricity is from nuclear fuels.
b. Excluding hydroelectricity but including non-commercial uses. *Source: Maillard, 1999.*

Despite the favourable developments in the energy market, energy security continues to concern planners and strategists in most importing countries.

have become more like traditional commodity markets (with futures markets), transparent and able to respond quickly to changing circumstances.

Big strides have been made in energy efficiency, gradually reducing the dependence of economic growth on increased oil consumption. Advances in technology have led to discoveries of more oil, reduced the cost of discoveries, and significantly improved the recovery rate, increasing the oil resource base to an estimated 2,300 trillion barrels. World trade has flourished in recent years. In 1998 it was three times that in 1980, and now accounts for 44 percent of global GDP, compared with 39 percent in 1980. Both energy exporters and importers benefit from trade. Most exporters are low-income countries that badly need oil income for development.

Even with the increase in oil-producing countries, the fact remains that almost two-thirds of the world's oil resources are in the Middle East, mostly in the Gulf region (the Islamic Republic of Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates). Although these six countries now account for only 27 percent of global crude oil supplies, they are expected to double their share to 52 percent in 2010. The Middle East, particularly the Gulf region, has not been historically known for political stability and security. But as mentioned, the situation is improving.

OECD countries, which account for almost 80 percent of the world's economic activity and 63 percent of global oil consumption, are particularly dependent on oil imports. All OECD countries are expected to increase their dependence on oil imports over the next few years. Their oil imports, 56 percent of their energy requirements in 1996, are expected to rise to 76 percent in 2020 (table 4.2).

Asia-Pacific countries' crude oil imports are expected to increase to 72 percent of their requirements in 2005 (up from 56 percent in 1993). The Middle East is expected to account for 92 percent of the region's imports, with the Gulf countries the main source of supply. The Gulf region is expected to supply 18 million barrels a day to Asia-Pacific countries in 2010 (figure 4.3), far more than its expected total supplies to Europe and the United States of 12 million barrels a day. That is why oil security, particularly for the major oil-importing countries, and the stability of the Gulf region have such importance to overall energy security and the world economy.

TABLE 4.2. OIL IMPORTS AS A SHARE OF TOTAL ENERGY REQUIREMENTS IN OECD COUNTRIES (PERCENT)

OECD country group	1996	2010	2020
North America	45	63	63
Europe	53	74	85
Pacific	90	96	96
Total OECD	56	72	76

Source: IEA, 1998.

This importance will only increase in the future.

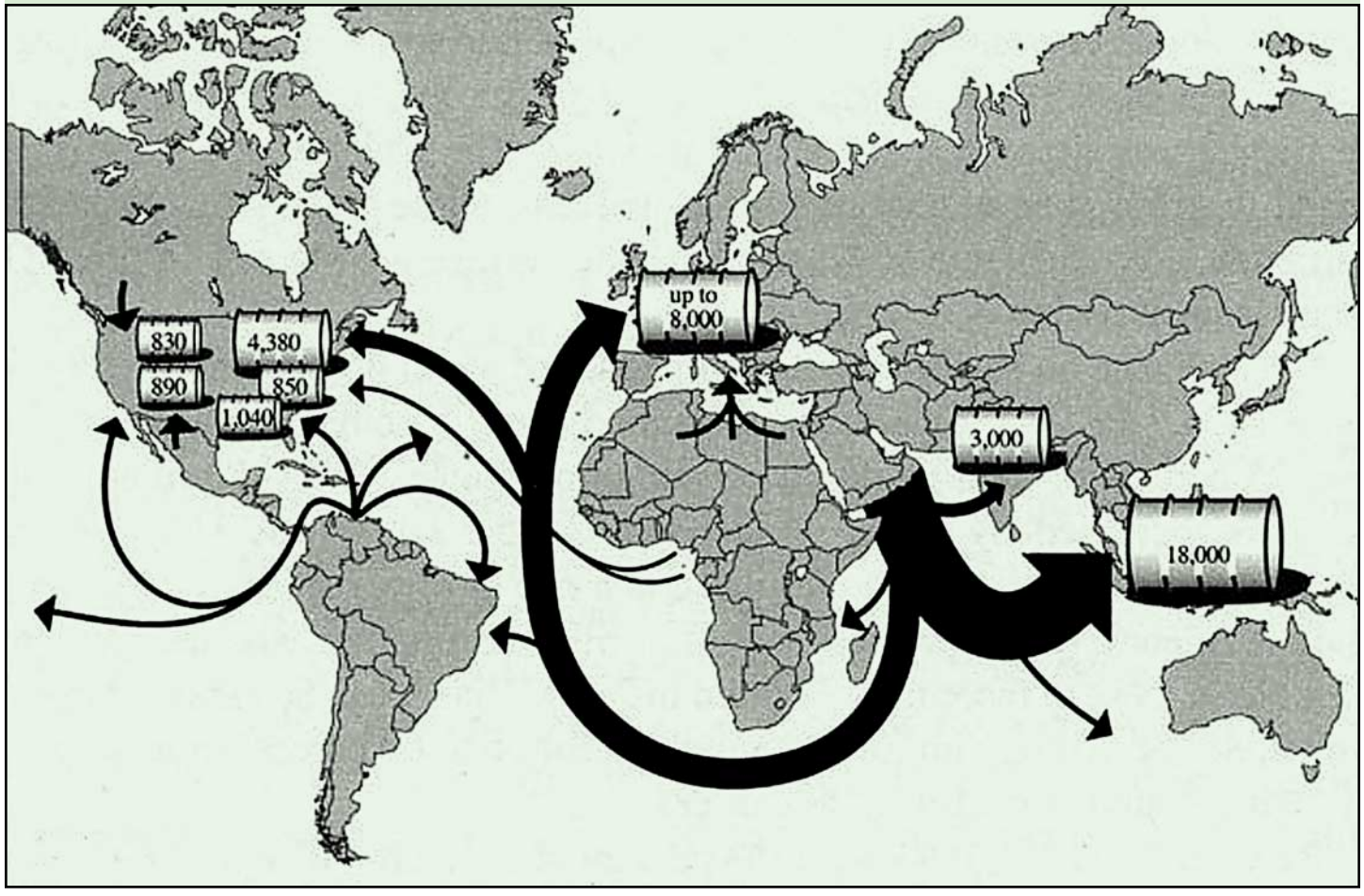
Differences between regional requirements and regional supplies will be accentuated in the future. Nowhere will this be more serious than in Asia, particularly among the large oil-consuming countries—China, India, Japan, and the Republic of Korea. Competition for supplies may intensify during emergencies, creating a potential for severe strains among Asian powers. Shortages may tempt some of these countries to project political and even military power to ensure adequate oil supplies. Already some of them—as well as the United States—have increased their naval presence in the Asian and Indian oceans (Jaffe, 1998). And U.S efforts for cooperation and conflict resolution are linked to its military planning and presence in the Gulf region and key oil export sea routes (Kemp and Harkavy, 1997).

Threats to security in oil-exporting countries can be both internal and external. Continued supply from Saudi Arabia is the most important element of energy security. Saudi supplies, now more than 9 million barrels a day, will have to increase to 13–15 million barrels a day in 2010 to meet growing world demand and offset resource depletion in non-OPEC suppliers. By that time the United States will be importing more than 60 percent of its oil. Saudi Arabia has both the potential and the reserves to meet projected demand, but the expansion will call for investment resources from that country as well as the world financial community. For a healthy oil sector, the availability of such financing should be no problem. Over the past few decades the Gulf countries have proved to be stable; continued internal and external stability is crucial to energy security. Disruption of the Gulf oil flow would lead to a deep world-wide recession. This has been presented as one of the gravest threats imaginable to U.S. interests, short of physical attack (David, 1999).

The cost of energy security goes beyond investing in redundant facilities and building pipelines, grids, and strategic reserves. Tremendous military expenditures—both visible and invisible—are required to head off any threats to the flow of oil, particularly from the Gulf countries. These costs cannot be easily computed or ascertained. The enormous expenditures on the 1990–91 Gulf War, totalling several hundred billion dollars, were meant to ensure energy security for major oil importers and the world oil markets in general. The six Gulf Cooperation Council (GCC) states, which control nearly 45 percent of the world's recoverable oil resources, contributed more than $60 billion to the U.S.-led allied offensive to eject Iraqi forces from Kuwait in 1991 (AFP, 1998). The GCC countries' contribution in 1991 exceeded their oil export income in 1998 or 1999. The United States maintains a costly military and naval presence in strategic locations to ensure the uninterrupted flow of GCC oil exports to world markets. At the beginning of 1998, along with the United Kingdom, it assembled large air and naval forces to address perceived threats to the security of oil supply from the Gulf.

Although short-term disruptions in energy supply due to regional

FIGURE 4.3. FLOW OF GULF OIL SUPPLIES, 2010



Source: Kemp and Harkavy, 1997.

conflicts cannot be ruled out, means to overcome such disruptions already exist. The best illustration of this is the minimal effect on oil markets from the Iraqi invasion of Kuwait in 1990. Although 4 million barrels of oil a day dropped out of the market, Saudi Arabia increased its production and restored stability to the oil market and to prices within a few weeks. Instruments for stabilising the oil market are improving year after year—strategic stocks held by oil companies and major importing countries, development and liberalisation of markets, and regional and global energy agreements. And once transport and transit issues are resolved, the Caspian Sea countries' hydrocarbon resources, as a supplement to the North Sea resources, can be added to this list.

Oil stocks: cushioning against supply disruptions. Oil stocks are usually held by oil companies for operational purposes, and by countries and state utilities to provide a cushion against unexpected surges in demand and possible disruptions in imports. Oil companies usually hold stocks that account for 55–65 days of consumption. International Energy Agency members are required to hold emergency oil stocks equivalent to at least 90 days of net imports. The European Union requires its members—also IEA members—to hold stocks equivalent to at least 90 days of consumption. It is not easy to estimate oil stocks held by developing countries. Because of the cost, their stocks are relatively smaller than those of OECD countries, but can amount to 25–55 days of consumption, which is also typical for oil companies in these countries. Correspondingly, world oil stocks in 1997 were about 5,500 million barrels, equal to 70–80 days of average global consumption. This, at present, is adequate for unexpected transient shortages or temporary interruptions.

With the continued growth of non-OECD oil consumption, oil stocks will function less effectively. Their size relative to the global oil market will decline, since most developing countries do not maintain emergency oil stocks (many cannot afford them). If this trend continues, vulnerability to sudden and substantial oil supply disruptions will increase.

Liberalisation of markets: easing the flow of oil. Another aspect of security is the liberalisation of energy markets in importing countries. Liberalisation and deregulation, coupled with the development of oil futures and forwards markets, mean an easier and more secure flow

OECD countries, which account for almost 80 percent of the world's economic activity and 63 percent of global oil consumption, are particularly dependent on oil imports.

of oil from exporting to importing countries. Most oil producers are now inviting foreign companies to participate in oil development, which will significantly enhance the security of the oil market. And the strengthening of the World Trade Organization will add further to the security of the energy market.

Although security in terms of flows of oil and gas to importing countries is improving, the security of supply to consumers faces new challenges. Liberalisation, the withdrawal of government responsibility for supply, and competition among private suppliers are creating challenges in securing reliable supply to individual consumers. These are discussed later in detail.

Energy treaties and agreements: enhancing energy security through cooperation. In response to insecurity after the first oil shocks, OECD countries convened a conference in Washington, D.C., in 1974 that led to the establishment of the International Energy Programme (IEP), the founding charter of the International Energy Agency (IEA). To improve energy security, the participating countries pledged to hold oil stocks equivalent to 90 days of net imports. They also developed an integrated set of emergency response measures that included demand restraint, fuel switching, and surge oil production. These measures also included the important provision of stock drawdown and sharing of available supplies in the event of oil supply disruptions involving a loss of 7 percent or more for any member country or for the group (Martin, Imai, and Steeg, 1996).

In 1977 the IEA developed another set of coordinated emergency response measures that allow for a rapid and flexible response to an impending oil security crisis. Also in that year, IEA countries agreed to long-term energy policies and programmes aimed at diversifying resources, employing energy efficiency measures, and developing new energy technologies. And in response to changing circumstances, the IEA updated its policies in a statement of shared goals at its ministerial meeting in 1993.

In 1991, 51 countries signed the European Energy Charter to enhance energy security throughout the Eurasian continent and promote the creation of an open and non-discriminatory energy market. The signatories included the European Communities and their member states, the countries of Central and Eastern Europe, all the members of the Commonwealth of Independent States (CIS), and Australia, Canada, Japan, and the United States. By applying the principles of non-discrimination and market-oriented policies, the charter was aimed at improving energy security, increasing the efficiency of all links in the energy chain, enhancing safety, and minimising environmental impacts.

Three years later, in 1994, all the signatories to the European Energy Charter (except Canada and the United States) signed the Energy Charter Treaty, along with a protocol on Energy Efficiency and Related Environmental Aspects, which entered into force in 1998. Japan and the Central Asian states have since signed the Charter Treaty and China is showing increasing interest in it, enhancing its geopolitical scope. The treaty applies to all economic activities related to a broadly defined energy sector. Its main purpose is to promote the creation of an open and non-discriminatory energy market throughout the Eurasian continent (Schuetterle, 1999). The Charter Treaty obligates signatories to encourage and create stable, equitable, and transparent conditions for foreign investors in their countries, stipulates that General Agreement on Tariffs and Trade (GATT) provisions will govern trade in energy materials and products, ensures the transit of energy exports through third countries, and sets out procedures for settling disputes relating to the treaty's provisions.

Also serving to enhance energy security are interregional and intraregional agreements established to foster economic cooperation between member countries, such as Asia-Pacific Economic Cooperation (APEC), which involves 21 economies of Asia, Oceania, and the Americas (box 4.3). Enhancing energy security is one of the aims of APEC, which set up its own Energy Work Group and the Asia Pacific Energy Research Centre (APERC) for this purpose.

No doubt the above-mentioned treaties and arrangements helped to foster energy investments and improve energy security—not only for their members, but also globally—by encouraging sustainable energy policies.

Oil in transport: a special point of vulnerability. The transport sector accounts for half of global oil demand, with heating, electricity generation, industrial processes, and petrochemicals accounting for the rest. Demand for oil in transport is growing rapidly, particularly in aviation. Over the next 20 years demand for oil in transport is expected to grow by 2.3 percent a year, compared with growth in total demand for oil of around 1.9 percent a year. Most of this growth will occur in non-OECD countries, where it is expected to average 3.6 percent a year, with the highest growth projected for China and East and South Asia. Demand in OECD countries, which are already witnessing some saturation in vehicle ownership, is expected to grow at one-third that rate.

In the near term there is no cheap and viable alternative to oil in transport, particularly in private vehicles and aviation (Douaud, 1999). Use of oil for mobility will increase in all countries, as the transport fleet grows and uses exceed improvements in transport efficiency. An interruption in oil supply, however temporary, could cause major disruption to the transport sector and to the world economy.

Oil prices: a source of insecurity. The severe volatility of oil prices in the 1970s and early 1980s contributed to the insecurity in energy markets. The price of oil is the market leader for energy pricing. Gas and coal, because of competition, are priced accordingly.

OPEC has the power to influence oil prices by allocating supply and monitoring and restricting production by its members. With the growing discipline in its ranks, this influence may increase in the future. Moreover, the depletion of non-OPEC oil and future growth in its marginal cost will increase oil prices in the medium and long

BOX 4.3. ASIA-PACIFIC ECONOMIC COOPERATION'S EFFORTS TO ENHANCE ENERGY SECURITY

Asia-Pacific Economic Cooperation (APEC) includes the following member economies in six 'sub-regions':

- The United States.
- Other Americas—Canada, Chile, and Mexico.
- China.
- Other Asia—Hong Kong (China), Japan, Republic of Korea, and Taiwan (China).
- Oceania—Australia, New Zealand, and Papua New Guinea.
- Southeast Asia—Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, and Thailand.

In addition, Peru, the Russian Federation, and Viet Nam joined APEC in November 1998.

APEC was formed to foster economic cooperation among its member economies, one aspect of which is energy cooperation and security. APEC economies' energy requirements account for more than half of the world's primary energy supply. The group has rich coal resources, and gas resources almost adequate for its requirements. But it is very short in crude oil resources. By 2010 APEC economies will have to import an estimated 55 percent of their energy requirements. The recent incorporation of Russia, with its enormous gas resources and its oil, has helped alleviate APEC's serious energy security problem. Nevertheless, APEC's significant crude oil shortages are expected to continue. APEC tries to enhance its energy security through the following actions:

- **Encouraging expansion of energy production.** The entry into APEC of Russia, with 40 percent of global gas reserves and 9 percent of oil reserves, should facilitate the development of energy resources in the Asian part of Russia and enhance the supply potential to the growing Asian energy market. The need for expanded production will lead to more energy development and greater cooperation between APEC economies and other energy-producing economies outside the traditional APEC region. The participation of firms from Asian oil-importing economies in upstream hydrocarbon resource activities will enhance efforts to expand oil and gas production. Similarly, the participation of firms from oil-exporting countries in downstream operations in Asian markets will contribute to the security of energy supply.
- **Allowing more flexible fuel choices.** As a group, APEC economies are heavily biased towards coal use. The main reason is that China, which accounts for a fifth of APEC's requirements, uses coal to meet more than 70 percent of energy demand. Institutional and technological changes to support more flexible choices that are compatible with sustainable development are being considered. Within APEC, nuclear options have been and will be pursued in the Americas and East Asia. In the Americas, however, nuclear power is expected to play a reduced role, while in East Asia nuclear power is expected to expand. In Southeast Asia there is no likelihood that nuclear power will be introduced before 2010.
- **Preparing for energy supply disruptions.** Emergency oil stocks, like those held by members of the International Energy Agency (IEA), are a key element of energy security. With the growth of non-IEA oil consumption, IEA emergency oil reserves will function less effectively, as their size relative to the global market will decline and most non-IEA countries do not maintain emergency oil stocks. If this situation persists, vulnerability to sudden and substantial oil supply disruptions will grow. The issue of emergency preparedness therefore needs to be examined in a broader context. For this reason the Asia Pacific Energy Research Centre is conducting a study to assess the value of emergency oil stocks in APEC economies.
- **Promoting energy reforms.** The increased competition resulting from regulatory reforms in energy markets promotes energy security in many ways. Yet despite the global trend towards energy sector liberalisation, some APEC economies in Asia still believe that energy security requires maintaining a regulated energy market. Attitudes towards deregulation are gradually softening, however, as long as it does not preclude the state from continuing to play a role when needed to enhance security.
- **Developing transborder energy delivery infrastructure.** APEC economies are examining the feasibility of developing transborder infrastructure. Members of the Association of Southeast Asian Nations (ASEAN) have studied the creation of both gas pipeline networks and electricity grids linking producer and consumer members. In Northeast Asia the concept of a gas pipeline network linking former Soviet economies (Russia and Turkmenistan, for example) with China, the Republic of Korea, and Japan has been discussed. Finally, Russia is promoting the idea of linking electricity grids with neighbouring economies. Besides economic viability, there are many other considerations in such projects: improved regional political stability through cooperation, better use of untapped resources, and increased capacity utilisation, energy supply, and demand diversity.

term. Prices will be further increased by the development of the more expensive non-conventional oil, once crude oil supply peaks around 2010. Although short-term price volatility, like that in 1998–2000, cannot be ruled out because of the many factors explained above, oil prices are not expected to be as volatile as in the past. After 2010 gradual, moderate price increases are expected. Many recent predictions have been made of future oil prices. Two of these are given in table 4.3.

Such moderate price increases, along with continuous improvement in energy efficiency, mean that oil prices are unlikely to place a more serious burden on the global economy than they do now. Moreover, the expected improvements in the real price of oil will spur producing countries to enhance and expand their production and provide them with the badly needed financial resources to do so.

Income security for oil-exporting countries. Some countries depend—for income and for development—on energy exports, particularly oil. This group is not limited to the Middle East; it includes a few countries in Sub-Saharan Africa and Latin America. Nor is this dependence on oil export income restricted to exporting countries; the benefits of oil export income spread to other countries in the region through wage remittances and financial assistance.

In the Gulf countries three-quarters of government revenue is derived from oil exports. Energy exports account for almost two-thirds of government revenue for other countries in the region, such as Algeria, the Islamic Republic of Iran, and Yemen. The dramatic drop in oil prices in 1998 and early 1999 led not only to budgetary problems in many energy-exporting countries, but also

TABLE 4.3. OIL PRICE PROJECTIONS (1997 U.S. DOLLARS PER BARREL)

Source of projections	1997	1998–2010	2015–2020
International Energy Agency	18.50	24.50	26.20
U.S. Department of Energy	18.55	21.30	22.73

Source: IEA, 1998; USDOE, 1998.

to unemployment and significant drops in incomes. Such economic problems were not only restricted to the oil exporters but were also experienced by their neighbours, which depend on revenues from exports of goods and services to the oil-rich countries and on remittances from workers in these countries. For energy-exporting countries, export security is becoming as important as energy import security is to resource-short countries. All this is enhancing the prospects for global energy security.

Dependence on oil exports has an additional implication for exporting countries. These countries, particularly OPEC members, are worried about the possible long-term impact on export demand of policies to mitigate environmental impacts, promote energy efficiency, and increase use of renewable energy sources. Although exaggerated in the short term, the potential impact could pose long-term problems for the countries, adversely affecting their economic and social development. Having met the needs of the global energy sector satisfactorily over the past 25 years, oil-exporting countries are asking for compensation if mitigation actions start to bite. This request is being reviewed in international negotiations. It may be many years before exporting countries' income is affected. Meantime, it is hoped that with international assistance and compensation, they will be able to diversify their income sources and reduce their dependence on oil exports.

Security of natural gas supply

Natural gas is slowly gaining importance in the energy market. Between 1987 and 1997 gas consumption increased from 1,756 giga cubic metres to 2,197, for an annual growth rate of 2.27 percent, compared with 1.47 percent for total primary commercial energy consumption. Over the period until 2020 natural gas demand is expected to grow still faster—at an annual rate of 2.6 percent, compared with 1.9 percent for oil. And natural gas supply, since it is starting from a much lower base than oil supply, is not expected to peak until well beyond 2020 (IEA, 1998).

Internationally traded natural gas accounted for 19 percent of gas consumption in 1997, compared with 44 percent for oil. So, just as for oil, though to a lesser extent, there is a mismatch between the location of gas supply and its consumption. Security of supply is therefore critical. But the physical characteristics of natural gas make ensuring security of supply for gas more complicated than for oil. Crude oil is an eminently fungible commodity, portable by ship, pipeline, road tanker, or even barrel. In contrast, gas requires expensive pipelines or LNG infrastructure. These delivery systems are relatively inflexible: pipelines cannot be moved or built overnight, and LNG, although somewhat portable, still requires an expensive receiving terminal. Crude oil and, more important, refined oil products can be transported to any location that can receive a ship or road tanker. Moreover, gas is difficult to store in significant quantities. The energy content per unit of volume is much lower for gas than for oil. Gas is simply more difficult to handle than liquid. Its storage often depends on the suitability of geological structures, while oil tank farms can be built relatively easily and cheaply. All these factors mean that the solutions used to ensure security of oil supply (storage, diversification of supplies) do not apply as easily to gas.

At its simplest level, gas supply security can mean operational reliability—in other words, that gas flows to the consumer when it is required. In particular, this means meeting consumer needs on days of peak demand, usually in winter. The gas supply system must be configured to give the required flexibility.

Security of supply also involves reducing strategic risk, namely, the risk of a major disruption to supplies caused by, for example, political factors or major technical failure, such as the failure of a high-pressure pipeline. This is an extension of operational security, but of a different order of magnitude. Strategic risk is growing in parallel with the growing share of gas in meeting countries' primary energy requirements. It can be reduced through:

- Interconnectivity, the degree of physical interconnection with other gas systems, an important factor in ensuring strategic security of supply. Interconnectivity is more than simply a guard against potential failure; it also encourages diversity of supply.
- Diversity of supply, which is fundamental to security of supply because it spreads risk. All sources of supply are unlikely to fail at the same time. Countries have often explicitly diversified supply by contracting with several countries. France, for example, buys gas from Algeria, the Netherlands, Norway, and Russia. In recent years there have been a number of spot LNG sales into Europe from LNG suppliers using spare capacity.

Security of supply also entails guarding against long-term risk—ensuring that consuming countries can secure future and additional supplies as their existing supplies are depleted. This represents a challenge, as the bulk of the world's gas reserves are in areas that are far from current markets and also often have a high level of country risk.

Some gas-importing countries, such as France, use long-term strategic storage to guard against significant disruption of supply. Such storage can be in depleted oil or gas fields, aquifers, salt caverns, or other geological structures.

Political risks to gas supplies and security of interregional grids. With the increase in internationally traded natural gas and LNG, political risk to gas supplies and cross-boundary networks will increase. One of the measures taken to reduce political risk is the Energy Charter Treaty, which attempts to provide a legal framework for the transit of hydrocarbons and electricity through pipelines and grids. The treaty prohibits contracting parties from imposing unreasonable charges for the transit of energy or taking unreasonable or discriminatory actions. Most important, in the event of a dispute over transit, transit states may not interrupt or reduce existing transit until the parties have had an opportunity to resolve the dispute using the treaty's dispute resolution mechanisms. As a further aid to international gas trade, the treaty prohibits countries from refusing new transit or new capacity to other treaty signatories solely on the basis of the origin, destination, or ownership of the energy being transported.

Tremendous military expenditures—both visible and invisible—are required to head off any threats to the flow of oil.

Political risk is also an issue for investment in the gas industry. Because of the capital intensity of the industry, a sound investment environment is needed to encourage companies to invest. This requires clear legal, fiscal, and contractual frameworks; transparent regulatory processes; and regulatory certainty. To improve the international investment environment for projects involving the transit of gas as well as oil and electricity across national boundaries, the Energy Charter Conference, an intergovernmental body made up of the 51 states that have signed the Energy Charter Treaty, began in 1999 to elaborate the Multilateral Transit Framework Agreement. The aim is to strengthen the international rule of law on transit issues by further developing the treaty's transit provisions.

With increasing utilisation of gas, lengthy gas pipeline grids across countries and boundaries are becoming familiar. This raises concerns about political and security problems relating to the integrity of the pipeline and continuity of supply—because of possible regional disputes, disagreements among firms, or accidents or sabotage. One of the principal aims of the Energy Charter Treaty is to provide for such contingencies. But not all countries are signatories to the treaty, though the numbers are increasing. However, the treaty provides guidelines (explained above) that non-member countries can incorporate in agreements relating to cross-boundary pipelines. Moreover, the increasing strength of markets, the World Trade Organization regulations, and the increasing interdependence of markets and countries enhance the security of supply from regional gas grids.

Natural gas is an ideal fuel for electricity generation. It is environmentally benign compared with coal and offers the potential for very high efficiencies in combined cycle plants. Like oil, natural gas resources are unevenly distributed across the world, but unlike oil, gas is not easily transportable or tradable. Expensive interregional gas grids are a solution as long as security is guaranteed, an aim of the Multilateral Transit Framework Agreement. Interregional grids provide benefits to all—suppliers, consumers, and transit countries. In addition, the increased security inherent in pipeline systems enhances cooperation among the countries involved.

Satisfying the increasing energy demand in India and South and East Asia may require building a very large interregional pipeline from the Islamic Republic of Iran or the Gulf. This would require not only a huge investment but also a coordinated regional arrangement and guarantees. Such a pipeline could sustainably meet the increasing demand for electrification in parts of Asia that account for more than a third of the world's population and where electricity demand is growing at twice the world average.

Risks to internal security of supply. In addition to the external risks, internal security risks are on the increase. These include the risk of electricity shortages due to increasing dependence on gas in electricity production. This increasing reliance on gas also raises supply security issues because of the possible domino effect in the event of gas supply problems. As a result of an interruption in gas supply to gas-fired power stations, a national grid could find itself short of capacity just as demand is peaking. Such security risks can be reduced, however, through coordination between the gas grid and the electric utilities, by switching combined cycle gas turbines (CCGT) to other fuels in the event of gas shortages, and by diversifying the energy sources for power generation (coal, nuclear, oil, gas, and hydro).

Diversity is more important than origin of supply. The mechanisms for securing diversity can be based on market instruments (payments for reserve capacity) or regulation (requirements for storing a certain number of days' worth of backup fuel supply). The U.S. gas market has shown how the price mechanism can enhance security of supply during less severe shortages. Many power stations burn both fuel oil and natural gas. As gas prices rise and the supply-demand balance tightens, the generators switch to the cheaper fuel, freeing up supply for gas consumers who cannot switch.

Development of national gas markets. Traditionally, international gas trade has been conducted on the basis of long-term (several-year) take-or-pay contracts. Under these contracts, designed to manage risk, the buyer agrees to take a certain volume over a period of time and to pay for that volume regardless of whether it is actually used. In effect, the buyer takes all the volume risk (the risk as to how much gas the end-use market will actually consume). The seller agrees to sell a certain quantity at a price indexed to such factors as the price of competing fuels, the price of electricity, and producer inflation. The seller therefore takes the risk that this price will cover its costs of production and provide a return on its investment. This is completely different from a commodity market, where supply and demand balance at whatever is the market-clearing price.

The 'traditional' take-or-pay system also frequently involved either monopsony or oligopoly buyers such as the European utilities (including the old British Gas and Gaz de France) and the Japanese utilities (Tepco). It has been argued that such a system was the only way to match supply and demand, ensure orderly development of the market, and allow all parties to recoup their investments. The approach has evidently worked: the record on gas supply security in Europe and Japan has been exemplary.

Recently, however, attention has focused on the implications of the liberalisation of gas markets for security of supply. In the United States the natural monopoly aspect of gas supply, gas transport by pipeline, has been separated from the other functions—production, wholesale, and retail. Regulated third-party access has given any gas producer the ability to transport its product to the end market, and any customer the ability to buy gas from any producer or wholesaler. In short, the approach has enhanced U.S. supply security. But the U.S. experience cannot necessarily be applied to other countries.

Long-term take-or-pay contracts do not completely eliminate

political or commercial risks. If a country is unable or unwilling to export its gas reserves for whatever reason, who has legal title to them is irrelevant. What such contracts can do, and have done in the past, is to give the parties a degree of confidence in the viability of a project and help secure financing.

By separating transport from supply, liberalisation, over the long term, will encourage the producers able to supply the market at lowest cost to meet consumers' demand. Moreover, the U.S. experience suggests that as pricing of gas supply and associated services becomes more transparent and explicit, market participants will search for the most cost-effective way of ensuring gas supply. In the United States this has led to greater and more innovative use of storage. The results depend, however, on how the industry structure and regulations evolve—whether dominant players effectively keep out new entrants, for example, or a more level playing field develops.

In summary, while the physical characteristics of gas make supply security problematic, it can nevertheless be enhanced by a variety of mechanisms, enabling gas to continue to play its part in the world's energy balance. Liberalisation of energy markets is not incompatible with supply security, and can arguably enhance it.

Security of coal supply

Coal presents fewer challenges—other than environmental ones—to energy security than do oil and gas. It is abundant and more evenly distributed around the world than oil or gas. It is cheap, and costs are continuously being reduced by competition. The many suppliers and the possibility of switching from one to another mean supply security. The global ratio of coal reserves to production is 225 years; for OECD countries, it is even higher. Coal is still a local fuel, however. International trade in coal is limited, amounting to only 13 percent of production, a smaller share than for gas.

The huge reserves of coal and their even distribution contribute to global energy security. Coal will continue to play a major part in ensuring the energy security of large energy consumers, particularly China (the largest coal consumer), the United States, and South Asia. Over the next few decades the growth in demand for coal is expected to continue to be healthy, exceeding the growth in overall energy demand.

Most of that growth will be for electricity generation, with coal consumption in the electricity sector expected to grow in all regions. But this is also the area where the main security challenge arises, because of the environmental effects of coal use—locally, regionally, and also possibly globally. Coal utilisation is very inefficient, particularly in power generation, where its efficiency is less than 25 percent (Ecoal, 1998). The efficiency of oil and gas in electricity generation is at least 50 percent higher.

For coal to play its deserved role in global energy security, its many detrimental environmental impacts must be addressed. This will require not only clean coal technologies for new plants, but also rehabilitation and refurbishment of existing inefficient plants. And this must happen not only in industrialised countries, but also in developing countries, which are expected to account for most coal use. All this calls for technology transfer and huge investments, which many developing countries will be unable to afford. Thus technical assistance to developing countries will be essential.

Nuclear energy and energy security

Nuclear energy could continue to add to the energy security of countries short of hydropower and indigenous fossil fuel resources, for several reasons. Uranium resources are widely distributed and abundant world-wide (see chapter 5). Nuclear fuel is cheap: at the price of present long-term uranium supply contracts, the cost of natural uranium per kilowatt-hour is equivalent to an oil price of $0.35 per barrel, so several years' supply could be kept in reserve against possible future supply disruption at a low cost. And the cost of uranium contributes only about 2 percent to the cost of nuclear electricity generation, compared with 40–70 percent for fossil fuels in electricity generation,[1] making the cost of nuclear electricity relatively insensitive to possible future increases in the uranium price.

These considerations played a key part in the decisions of such economies as France, the Republic of Korea, Japan, and Taiwan (China) to launch major nuclear power programmes. In all likelihood, such considerations will also be important determinants in similar decisions by countries with a shortage of indigenous resources and a heavy reliance on imports. Moreover, the fact that nuclear power releases virtually no environmentally damaging emissions of carbon dioxide, sulphur dioxide, and nitrogen oxide could make it an attractive option for many countries seeking technologies leading to reduced greenhouse gas emissions or abatement of local and regional pollution.

In the 1960s and 1970s, particularly after the first oil shock, nuclear power promised to be a viable solution for industrialised countries looking for energy security and cheap power. Largely as a result of investment decisions made in that period, nuclear power has grown to the point where it dominates electricity generation in several industrialised countries, providing about a sixth of global electricity in 1998. But the outlook for nuclear power is not bright. Most of the promise of nuclear energy has evaporated as a result of loss of investor and public confidence in the technology. There is likely to be growth in nuclear power in some Asian countries in the period to 2020 and modest expansion at the global level until 2010. But most projections show nuclear power accounting for a smaller share of global electricity generation in 2020 than today, and many show its absolute contribution staying the same or even shrinking.

The loss of investor and public confidence in nuclear technology is due to concerns about costs, nuclear safety, radioactive waste disposal, and proliferation or diversion (see chapter 8). Until these concerns are adequately dealt with, nuclear energy is unlikely to play an expanding role in enhancing global energy security. The energy security benefits provided by nuclear power might even be diminished if there is another reactor accident involving substantial releases of radioactivity or a proliferation or diversion incident that could be plausibly linked in the public mind to nuclear power.

Recognition that another major accident might not only diminish

prospects for nuclear expansion but also trigger demands to shut down existing nuclear plants has catalysed private sector-led efforts, under the auspices of the World Association of Nuclear Operators, to instil a culture of safety in the world's nuclear industry. This situation has also prompted an international effort, led by the International Atomic Energy Agency, to bolster national nuclear regulatory regimes. This effort is embodied in the Convention on Nuclear Safety, adopted by the organisation's members. (For discussion of technological strategies for improving the safety of future reactors, see chapter 8.)

The Nuclear Non-Proliferation Treaty and associated international safeguards and nuclear supplier agreements have been implemented to minimise the nuclear weapons link to nuclear power (Murray, 1995). To date, all but a few states (apart from the five nuclear weapons states recognised in the 1968 Non-Proliferation Treaty, these are India, Israel, and Pakistan) have committed themselves to putting all nuclear material, including the material used for uranium enrichment and reprocessing, indefinitely under safeguard of the International Atomic Energy Agency.

Recent events and concerns about the limitations of existing policies have led various experts to call for further efforts to weaken the nuclear weapons link to nuclear power. But because the risk of proliferation and diversion is not at the forefront of public concerns about nuclear power (and may not be until there is an incident), because national policies in this area differ widely, and because there is much disagreement in the technical community about the best approaches for minimising this risk, there has been less action in this area than there has been in improving reactor safety. Increasing the authority and resources of the International Atomic Energy Agency for monitoring enrichment plants and spent fuel is the principal way immediately available to reduce the proliferation risks associated with existing uranium enrichment and fuel reprocessing capabilities. (For a discussion of institutional strategies for further weakening the nuclear weapons link, see Walker, 1998. For a discussion of future options for weakening this link with advanced technologies, see chapter 8.)

In summary, for the next couple of decades the prospects for enhancing energy security through expansion of nuclear power are not bright at the global level, although they are somewhat better in some Asian countries. In the longer term whether nuclear power can contribute to energy security depends not only on technical and economic considerations to be sorted out by the market, but also on the extent to which the public can be convinced that nuclear power is safe and that wastes can be disposed of safely. It also depends on whether the industry can avoid major accidents and proliferation and diversion incidents, and whether national and international policy-makers and the technical community can reach consensus on what needs to be done to make nuclear energy technology widely acceptable.

If the world economy continues to grow at the expected average rate of 2.7 percent, in 2020 global energy demand will be 45–51 percent higher than in 1998.

Energy intensity

One way to improve energy security in any country is by reducing its energy intensity—the amount of energy required to produce one unit of GDP. The rate of change in energy intensity reflects the overall improvement in energy efficiency as well as structural changes in the economy. Declining rates of energy intensity indicate that economic growth is less tightly linked to increases in energy use.

Energy intensity has improved considerably in industrialised countries. In the United States over the past two centuries it has declined 1 percent a year on average. One unit of GDP now requires only a fifth of the primary energy required 200 years ago (IIASA and WEC, 1998). In the past 15 years energy intensity in the United States has improved 20 percent.

Energy intensity differs depending on the level of economic development. OECD countries generally have an energy intensity that is a fraction of that in developing countries. In 1996 the commercial energy intensity of middle-income developing countries was three times that of high-income countries. This finding remains whether GDP is measured in market dollars or in purchasing power parity (PPP) terms. In most developing countries energy intensity is stagnant or even increasing because these countries are in the early take-off stages of industrialisation, when energy-intensive industries and infrastructure are being established. Moreover, low-income developing countries usually show increasing commercial energy intensity because commercial energy sources are replacing non-commercial fuels.

The prospects for lowering energy intensity are reduced in many developing countries by the proliferation of energy price subsidies and by the use of inefficient and outdated plants and equipment. Generally, however, energy intensity in developing countries is similar to that in industrialised countries when they were at an earlier stage of development.

Economic growth in developing countries has been relatively high in recent years, averaging 2.8 percent a year in the 1990s, compared with 2.1 percent for industrialised countries and 2.3 percent for the world. This trend is likely to continue. If this growth is matched by measures to conserve energy—such as phasing out subsidies and improving environmental awareness—energy security in developing countries is likely to continue to improve as well.

Predicting the future of energy intensity is difficult, particularly for developing countries. In low-income countries energy intensity may increase in the next few years as these countries substitute commercial energy for traditional fuels. But for the world as a whole, energy intensity is likely to improve. Average improvements will range from 0.8 percent to 1.0 percent a year, depending on such factors as environmental awareness and energy prices (IIASA and WEC, 1998). If the world economy continues to grow at the expected average rate of 2.7 percent, energy demand growth will average 1.7–1.9 percent a year. That means that in 2020 global energy demand will be 45–51 percent higher than in 1998. This is

The increased use of electricity as an energy carrier world-wide will further improve energy efficiency.

a substantial increase. But without the expected efficiency improvements in global energy utilisation, the demand could grow as much as 80 percent.

The potential for efficiency improvements is high in many energy applications (see chapter 6). Some of the most important progress in energy efficiency is that taking place in the conversion of energy to electricity. Modern combined cycle gas turbines burning natural gas have efficiencies approaching 60 percent, and efficiencies of 70 percent are within reach in the foreseeable future. Such efficiencies are more than double the average of 31 percent for the world stock of existing generating plants. As old plants are phased out and new, CCGT-type plants—or the traditional thermal generating plant firing coal at more than 40 percent efficiency—take over, considerable improvements in energy utilisation will gradually occur. In addition, the increased use of electricity as an energy carrier world-wide will further improve energy efficiency. In some applications electricity is more efficient than other forms of energy, and its use is now growing 2.8–3.2 percent a year, a rate more than 50 percent higher than that for primary energy overall (Khatib, 1997). All this will significantly lower energy intensity and thus improve prospects for global energy security.

The environment and energy security

The idea of sustainable development is gaining acceptance on the official level as well as among the public. Sustainable development demands environmental preservation. Energy production and utilisation, particularly in the case of fossil fuels, can be major sources of environmental degradation. These detrimental environmental impacts have a direct bearing on the future of energy—in terms of fuels and the extent of their use—and on energy security. (For a discussion of the environmental impacts of energy use, see chapter 3.)

The United Nations Framework Convention on Climate Change, adopted at the Rio Earth Summit in 1992, and the Kyoto Protocol, signed by more than 160 countries in 1997, call for major reductions of greenhouse gas emissions, which are caused mainly by energy use. Fulfilling the commitments as agreed and at the schedules approved would greatly affect the use of energy resources and could compromise global economic progress. There is a large gap between the commitments and the means for implementation. Targets agreed upon by negotiators were not necessarily implemented by legislators or other policy-makers. Implementation of such targets is hindered not only by cost but also by the need to maintain energy security.

All indications are that fossil fuels will continue to dominate global energy resources for at least the first decades of the 21st century. Moreover, the demand for energy services will continue to increase. Most of the growth will be in developing countries, which can ill afford the high cost of containment measures. It is therefore essential to find means to contain energy-related emissions without compromising energy security.

The environmental effects of energy use occur at the local, regional, and global levels. Local effects consist primarily of heavy hydrocarbons and particulate matter (including sulphur flakes) that are deposited within hours and can travel up to 100 kilometres from the source. Regional effects include emissions and effluents, the most important of which are sulphur and nitrogen oxides, which are converted into acids; these acids, which last for a few days in the atmosphere, may travel up to a few thousand kilometres before being deposited, often after crossing boundaries. Global environmental impacts are exemplified by emissions of carbon dioxide and other gases (mainly methane) that have long residence times in the atmosphere.

Local and regional impacts can be addressed by technologies. However, some of these technologies are expensive for developing countries, where growth in the use of low-quality coal will be particularly high. There are no easy answers in dealing with greenhouse gas emissions. Mitigation and sequestration measures are still to be developed. The most practical solution is to reduce the growth in fossil fuel use by increasing efficiency in energy utilisation.

Enhancing efficiency in energy use not only helps greatly to mitigate emissions; it also improves energy security. But for greater benefits for energy security, energy use should also be made more compatible with the aims of sustainable development through better containment of emissions. Such simple measures as washing coal will rid it of 20–50 percent of its sulphur. Advanced burners and scrubbers remove pollutants and effluent gases from smoke stacks and chimneys. Fuel substitution is another effective measure. A modern CCGT power station, firing gas, will emit only 40 percent as much carbon dioxide as a traditional coal-fired thermal power station. The slow but persistent growth in the use of electricity as an energy carrier will also contribute towards energy security. Besides offering greater efficiency than other forms of energy in many applications, electricity concentrates emissions in a single remote location—the site of the power station—making them easier and cheaper to deal with.

Markets and energy security

Approaches to ensuring energy supply security in the 21st century should differ from past approaches that concentrated on oil substitution. Besides sustainable growth challenges, new approaches need to tackle the new energy security issues raised by market liberalisation.

The enhanced role of markets is tied closely to the process of globalisation. Globalisation, which is still gaining momentum, has encouraged competition and strengthened markets and regional and international trade, particularly for crude oil and oil products, natural gas, and energy services. Globalisation is bringing new opportunities for energy security, such as better access to markets and services and the transfer of technologies that are helping to reduce the cost of energy exploration and expand proven reserves.

International trade in energy resources and services is vital for energy security. The creation of the World Trade Organization in 1995, built on the GATT, is the latest multilateral step towards creating an environment conducive to the exchange of goods and services. It will assist in trade liberalisation and allow countries greater

recourse to trade dispute settlement mechanisms. Foreign trade has grown more quickly than the world economy in recent years, a trend that is likely to continue. For developing countries, trade is growing faster than national income, reaching 50 percent of GDP, and a good share of that trade is in energy. The flow of information has become much easier and more transparent, increasing the resources and services available for trade and reducing prices. All this aids greatly in enhancing energy security.

The introduction of a single market in Europe will lead to more competition in energy services and supply of cheaper electricity. Improvements in transport networks and technology are reducing the cost of energy trade. The liberalisation of European gas and electricity markets will initiate major structural changes in European energy enterprises, increasing competition, improving economic performance, and contributing towards fuel diversification and greater energy security (EC, 1999).

In studying the influence of markets, there is a need to distinguish between OECD countries, where free markets prevail, and developing countries, where market liberalisation is still at a very early stage. Security of supply is a public policy objective. But in free markets decisions are made by market players rather than by governments. Markets allow even small and medium-size consumers—as well as suppliers—a say in energy decisions. That requires redefining the political dimension of energy security.

Markets clearly produce benefits for consumers: trade, innovation, cost reduction, technological advances, and better allocation of resources. Moreover, unbundling the supply chain enhances transparency and allows tariffs to reflect real costs. Markets have also taught us a few lessons: they have proven that they can adjust more easily than governments to changing circumstances in the energy market and that it is costly to intervene against the market for an extended period.

Market liberalisation is leaving much of the decision-making to consumers. Are the consumers capable of making the right choices? Or would they choose cheaper options (such as interruptible supply) even if that compromises their energy supply security? This possibility suggests a need for a government role. Moreover, liberalisation will not necessarily cover the entire supply chain. Certain monopolies will remain in transmission and distribution. Governments therefore have a duty to protect consumers at the very end of the supply chain (retail consumers). In addition, the energy market may ignore the interests of other consumer classes, such as remote and isolated consumers. All this necessitates that government continue to be involved in the energy market to a certain extent in almost every country.

The argument applies particularly to the supply side. Energy development entails long-term, capital-intensive investments. Private investors may demand a higher rate of return in a liberalised market than in a government-controlled energy industry. In addition, markets usually look for short-term profits and may therefore forgo diversification of supplies, which is associated with high up-front investment and risk but long-term benefits. How will markets respond to the long-term requirements of sustainable development, which demands heavy investments in research and development? How can they meet societies' long-term interest in secure supplies at reasonable prices when their interest is mainly in the short term? How can markets respond to an emergency disruption of supply in exporting countries? The division between the production and supply functions does not allow full integration of the security function. Will the energy markets be able to internalise all the costs of security, including political risk?

Having said all that, there are several reasons to believe that regulatory reforms in the energy market that are aimed at enhancing competition would promote energy security. First, as discussed, reforms can lead to increased investment and trade in energy resources, which will, in turn, facilitate expansion of energy production, increase inter-fuel competition, and encourage the construction of transboundary energy delivery infrastructure, such as oil and gas pipelines.

Second, also as discussed, the participation in downstream operations by firms from oil-exporting economies, and the participation in upstream operations by firms from oil-importing economies (all of which is facilitated by market liberalisation), will be mutually beneficial and thus increase both exporters' and importers' interest in energy security. In Asia deregulation and other energy sector liberalisation will also promote accelerated growth in energy supplies and a greater sense of energy security.

Third, regulatory reforms will enhance efficiency and effectiveness, even in the area of energy supply emergency response. The IEA's oil supply emergency systems place growing emphasis on drawdowns of oil stocks compared with such measures as demand restraint. The release of oil stocks into the market is more market-oriented than government intervention to restrain demand.

Thus energy sector regulatory reforms could be compatible with or even enhance energy supply security. Governments, while withdrawing from energy investments themselves, need to create a positive climate for trade and investment. With increasing market liberalisation, there is a growing need for governments to monitor private sector actors and deal with market failures. Certain investors might be looking for concentration through mergers and joint ventures, for example, which might conflict with government policy of promoting liberalisation and fostering competition.

In considering the role of markets, the following questions are increasingly asked: Can the important issue of energy security be left entirely to markets? What is the role of the state in ensuring energy security in a liberalised market environment?

The role of the state

Markets are playing an increasingly progressive role in energy. This role is prominent in most OECD countries, modest in some developing countries, and absent in others, where the state remains almost solely responsible for the energy market and the security of supplies and services.

In a globalised market economy, energy security becomes a matter of prices, economic growth rates, and wealth transfers. In an energy (oil) crisis it cannot be assumed that free market conditions will prevail throughout the crisis (Jaffe, 1998). Thus the state still has an important role to play in almost in every country:

Markets usually look for short-term profits and may therefore forgo diversification of supplies.

- Sending clear signals to markets so that they can be guided by the state's long-term energy policy.
- Continuing to act as a regulator to ensure fair play in the market.
- Ensuring long-term security by making the bold or costly decisions that the market cannot make on its own, such as diversifying fuels and encouraging renewables.
- Preserving the environment and enforcing environmental policies.
- Holding oil stocks for supply security and coordinating with other governments in such arrangements.
- Collecting and disseminating accurate energy market information in the event of emergencies. Left on their own, markets may respond nervously to rumours or distorted information, adding to the confusion and insecurity. Official information systems greatly helped to calm the markets in 1991 following the Gulf war and restored market stability.
- Financing and investing in research and development of new energy technologies and in improving efficiency, and encouraging markets to invest in research and development by offering tax and other incentives.
- Trying to incorporate the 'externalities' (such as long-term assurance of supply, environmental protection, and protection against possible disruptions) in a market-oriented setting.

Structural reforms are helping to foster competition by liberalising markets, but such competition and cost cutting should not be allowed to threaten long-term security of supplies to final consumers. That remains a government responsibility.

Regional cooperation and the growing importance of regional electricity grids and network energies

Use of electricity is growing more rapidly than use of all energy services. Over the next 20 years electricity production is expected to increase by about 3 percent a year, compared with average growth in total energy use of less than 2 percent a year. With this will come growth of electricity grids and regional interconnections. National and regional natural gas networks are also growing as reliance on gas increases because of its price and its environmental attractiveness. All this reflects consumers' growing preference for network energy. Energy security for consumers is thus no longer limited to the availability of resources and geo-political considerations. It is becoming increasingly dependent on markets and competition and on the security of regional networks, a vitally important issue.

Interconnection of neighbouring national grids (electricity and gas networks) into regional grids greatly enhances energy security. It also reduces the cost of supply by taking advantage of differences in peak demand and by allowing a reduction in standby power and reserve generating capacity and the use of cheaper resources. Today regional electricity grids exist not only in Europe but also in many other parts of the world. While the increasing interconnections across borders are providing great benefits to consumers, supply interruptions still occur, mainly because of problems in the local distribution system.

Conclusion

- All indications point to a gradual but steady improvement in energy security in all parts of the world, thanks to technological advances, adequacy of resources, and regional cooperation, energy agencies and treaties, and international trade organisations.
- Present energy security aims go beyond merely ensuring the availability of abundant oil supplies at affordable prices. They also include ensuring long-term energy adequacy in a new economic environment of deregulated and liberalised markets and fostering sustainable development.
- The resource base of fossil fuels is clearly adequate for meeting global energy service requirements well into the second half of the 21st century. But the resources—particularly crude oil and, to a lesser extent, gas—are mismatched between regions and between consuming and producing countries, raising geopolitical questions. Oil resources are heavily concentrated in the Gulf region, a part of the world that has experienced security problems. However, recent trends in energy utilisation and oil technologies are contributing greatly towards stability of supplies and prices in the oil market.
- The world will continue to depend on fossil fuels for decades to come. But these fuels have detrimental impacts on the environment that must be dealt with to achieve sustainable development. This requires promoting clean energy technologies, pursuing energy efficiency, developing renewable forms of energy, and providing technical assistance to developing countries, where most growth in energy use will take place.
- Deregulation and market liberalisation pose questions for energy security and for the future role of the state with respect to energy security. Markets lead to innovation, reduce costs, increase trade, improve allocation of resources, and spur technological development, all of which enhance energy security. Markets also normally pursue short-term objectives, while energy security demands long-term planning, investment, and political will. The state therefore needs to continue to play a role in ensuring national long-term security of supplies and protecting consumers.
- Consumers are gradually opting for energy supplied by grid (electricity and gas). This greatly enhances security of supply, reduces costs, and fosters regional cooperation.
- With energy services increasingly being supplied by electricity, the security of the electric power supply, in terms of both continuity and quality, is becoming paramount. Interruptions, even transient ones, cause serious income and welfare losses for consumers. In many developing countries the security and availability of the electricity supply leave much to be desired, pointing to a need for capital investments. The steady expansion of regional electricity grids, however, is helping to improve the security of electricity supply. ■

Note

1. The total nuclear fuel cycle cost, including enrichment and other fuel processing services, contributes 15–20 percent to the cost of nuclear electricity, but the cost of uranium presently accounts for only about 10 percent of the nuclear fuel cycle cost.

References

ADB (African Development Bank). 1999. *Infrastructure Development in Africa.* Abidjan.

AFP (Agence France-Presse). 1998. "Gulf States Cannot Afford to Finance Another War." *Jordan Times,* 16 February, p. 10.

Campbell, C.J., and J.H. Laherrere. 1998. "The End of Cheap Oil." *Scientific American* 278: 60–65.

David, S.R. 1999. "Saving America from the Coming Civil Wars." *Foreign Affairs* 78: 103–16.

Douaud, A. 1999. "Automotive Fuels." *Oxford Energy Forum* (36): 18–19.

EC (European Commission). 1999. "Economic Foundations for Energy Policy." *Energy in Europe* (special issue, December): 1–170.

Ecoal. 1998. *World Coal Institute* 28(1).

IEA (International Energy Agency). 1998. *World Energy Outlook.* Paris.

IIASA (International Institute for Applied Systems Analysis) and WEC (World Energy Council). 1998. *Global Energy Perspectives.* Edited by Nebojša Nakićenović, Arnulf Grübler, and Alan McDonald. Cambridge: Cambridge University Press.

Jaffe, A. 1998. "The Political, Economic, Social, Cultural and Religious Trends in the Middle East and the Gulf and Their Impact on Energy Supply, Security and Pricing—Energy Security." Rice University, Baker Institute, Houston, Tex.

Kemp, G., and R. Harkavy. 1997. *Strategic Geography and the Changing Middle East.* Washington, D.C.: Brookings Institution Press.

Khatib, H. 1997. *Financial and Economic Evaluation of Projects.* London: Institution of Electrical Engineers.

Maillard, D. 1999. "Energy Security." Ministry of Economy, Finance, and Industry, Paris.

Martin, W., R. Imai, and H. Steeg. 1996. *Maintaining Energy Security in a Global Context.* New York: Trilateral Commission.

Masters, C.D. 1994. *World Petroleum Assessment and Analysis.* Proceedings of the 14th World Petroleum Congress. New York: John Wiley & Sons.

McKelvey, V.E. 1972. "Mineral Resource Estimates and Public Policy." *American Scientist* 60: 32–40.

Mitchell, J.V. 1997. *Will Western Europe Face an Energy Shortage?* Strasbourg: Energy Council of France.

Murray, J. 1995. "Nuclear Non-proliferation: Challenges for the Future." Speech to the Australian Institute of International Affairs, Melbourne, December.

Newton-Evans Research Company. 1998. *Market Trend Digest* (summer). Baltimore.

Schuetterle, P. 1999. Secretary-General of the Energy Charter. Personal correspondence. January.

USAID (U.S. Agency for International Development). 1988. *Power Shortages in Developing Countries: Magnitude, Impacts, Solutions, and the Role of the Private Sector.* Report to U.S. Congress. March. Washington, D.C.

USDOE (U.S. Department of Energy). 1998. *Annual Energy Outlook 1999.* Washington, D.C.

Walker, W. 1998. "Nuclear Power and Nonproliferation." In M. Poireau and A. Zurita, eds., *Nuclear in a Changing World: Proceedings of the European Seminar.* Vol. 2. XII/0318/98.EN. Brussels: European Commission, Directorate-General XII, Science, Research and Development.

WEC (World Energy Council). 1998. *Survey of Energy Resources.* London.

World Bank. 1999. *World Development Report 1999/2000: Entering the 21st Century.* New York: Oxford University Press.