Nuclear power development in Asia

Fast-growing national economies and electricity needs are driving plans to introduce or expand the use of nuclear power

by Chuanwen Hu and Georg Woite

Asia — the continent with the largest population in the world — has achieved significant economic growth within the past decades. In many countries, the rapid population and economic growth has brought a tremendous demand for energy and electricity — one which fossil fuels and hydropower together will not be able to meet. Nuclear power is thus expected to become an important option for meeting the region's long-term electricity needs on a sustainable basis.

In Japan and the Republic of Korea, for example, successful and ongoing nuclear programmes now account for a large share of total electricity generation. The People's Republic of China and India, as the world's two largest developing countries, are actively proceeding with national nuclear energy programmes. Several other Asian countries have announced their intentions to consider nuclear power deployment in their long-term energy plans.

This article examines recent energy developments in the region, and most specifically the status and prospects of nuclear power. In so doing, it briefly reviews aspects of population and economic growth, energy demand, and environmental and financial constraints of energy supply in Asia, and looks at diverse national situations concerning the potential role of nuclear energy.

Economic and energy developments

Nearly 60% of the world's people live in Asia, where most countries have quite low levels of gross national product and *per capita* energy consumption. South Asia is one of the regions with the highest population growth rates in the world, and this trend is expected to continue up to the end of this century and beyond. Most people live in rural regions and they use very little commercial energy. Greater urbanization and improving living standards in the future, however, will lead to higher demand for energy supply with growing emphasis on commercial energy, in particular electricity. Rapidly growing economies in many Asian countries are driving forces for increased energy demand. This situation has aggravated existing power shortages in the region, and power cuts and rationed supply are routine in municipal areas.

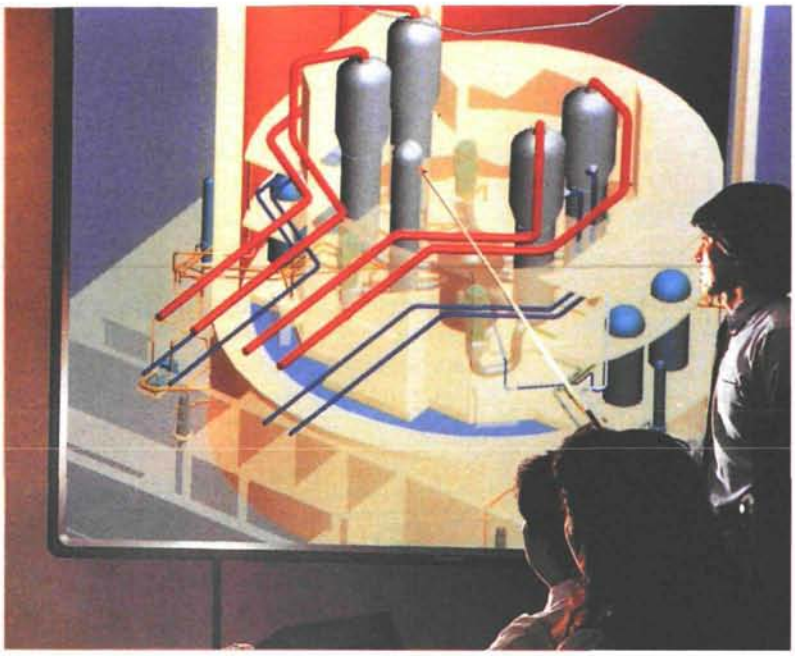
Electricity use *per capita* in most Asian countries is substantially lower than that of industrialized countries. As compared with more than 10 000 kWh *per capita* per year in the USA, Sweden, and Canada, the electricity uses *per capita* per year in India and China were only 305 and 515 kWh in 1989, respectively. Electric system expansion is urgent for sustaining national economies.

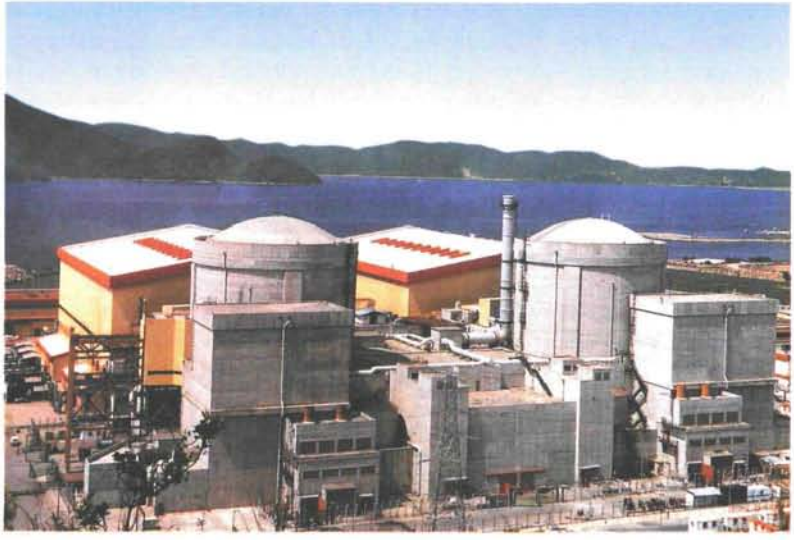
In China, to support the country's rapid economic growth (over 10% per annum) during the past decade, the total installed electrical generating capacity has more than doubled, reaching 150 gigawatts (GWe) in 1991. In spite of this rapid increase, the electricity supply has been falling far short of demand in the fast-developing coastal areas of China. Twelve to 15 GWe of new capacity is expected annually up to the end of this century, when the total electrical generating capacity in China will reach about 260 GWe.

In India, power generating capacity was increased by about 5 GWe per year during the 1985-90 period. However, a peak deficit of more than 10 GWe and a power shortage of nearly 21 billion kWh were estimated for 1991 in India. The Indian Government's 1992-97 economic plan envisages a need for an additional 31 GWe of public-sector generating capacity.

In Indonesia, the generating capacity has doubled during the past 10 years, but it will have to be doubled again by 2000 to meet the estimated 10% annual growth in demand. The nation needs to install 35 GWe of additional capacity by 2015.

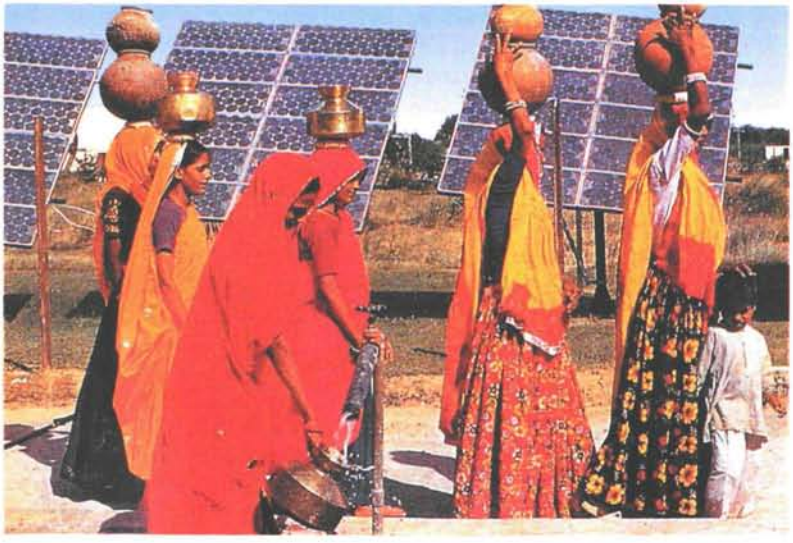
Messrs Hu and Woite are staff members in the IAEA Division of Nuclear Power.

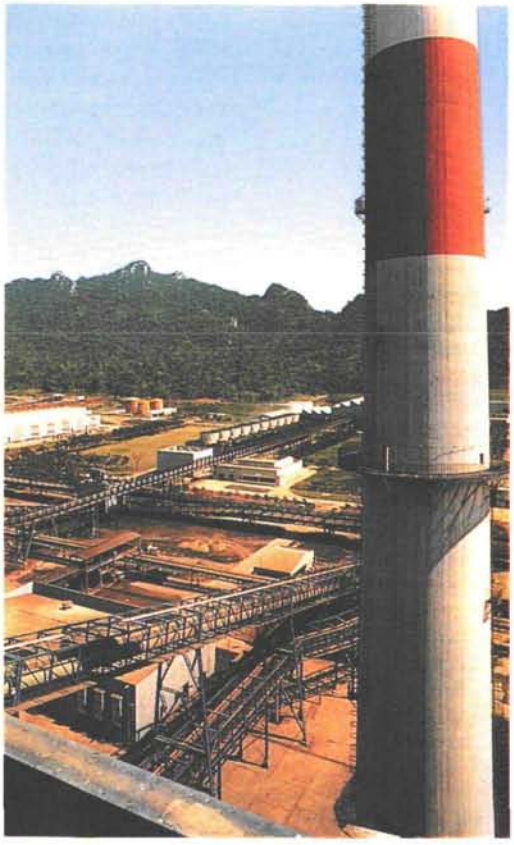




To meet Asia's rising electricity demands, nuclear power is among various energy sources being developed. *From top left:* New designs for nuclear plants being discussed in Japan; maintaining electric power lines in Indonesia; China's Guangdong nuclear plant at Daya Bay; solar panels in an Indian village; a coal-fired plant in Thailand.

(Credits: Mitsubishi; EdF; UNDP; ADB, HKNIC)





In Malaysia, electricity consumption rose 8% in 1989 and 15% in 1990. Malaysia's demand for power will almost triple by the end of the decade, to about 13 GWe from about 5 GWe now.

In Thailand, electricity capacity has rapidly increased in recent years (5.6% in 1989; 17% in 1990) and about 1 GWe of new capacity is needed every year.

In the Republic of Korea, electricity demand rose by about 13% to 14% annually between 1987-90. It is expected to rise about 4.5% to 6% per year until the year 2006.

It is estimated that throughout Asia soaring economic growth will lead to the doubling of electricity demand during the 1990s. The annual estimated additional power capacity needed in Asia is about 20 GWe per year, totalling nearly 200 GWe over the next decade.

Constraints on energy supply

At the present time, there is a big gap between energy supply and demand in Asia. Many diverse issues have obstructed the implementation of ambitious energy programmes that were planned. In the following sections, some major factors are investigated for different countries.

Resources. Several Asian countries, such as Japan (the world's largest importer of energy) and the Republic of Korea, have depended heavily on imported fuel for energy supply. The painful experience during the oil crises of the 1970s in these countries had major impacts on national energy policies. In order to ensure the long-term availability of energy, sustained and well-planned nuclear power programmes have been implemented in Japan, Republic of Korea and Taiwan, China. With growing domestic demand, Indonesia could turn into a net oil importer by the end of the decade. More than 20 GWe of new capacity are expected to be installed in Indonesia before 2003; however, under the current national limits on coal consumption (40 million tonnes per year), the maximum coal-fired capacity would be limited to 15 GWe. The government's studies have shown that a nuclear power programme would be feasible, although nuclear generated electricity would not be the cheapest option right now.

Environmental protection. Fossil fuels are the main energy source for electricity generation in Asia. China and India, the region's two biggest coal users, will continue to get the bulk of their power needs from coal. The burning of fossil fuel leads to quite large emissions of carbon dioxide, and sulphur and nitrogen oxides. China, Japan and India are among the world's major CO_2 emitting countries, ranking within the top-five in absolute terms. Asia's carbon dioxide emissions are estimated to increase by up to 30% until the year 2000. The releases of sulphur and nitrogen oxides have been causing serious pollution and significant damage to economic development and human health in the region. It is imperative to gradually reduce the share of fossil fuels and to adopt clean technologies for power generation

Transportation and transmission. The abundant coal reserves in both China and India are unevenly distributed geographically. Most of the fast developing areas, where consumption is concentrated, are far away from coal deposits. Even though about 40% of the total rail cargo capacity is taken up for coal transportation in China, the transportation network does not meet the demand. Insufficient capacity for coal transportation has become a bottleneck for economic development in the country's coastal areas.

Losses in transmission and distribution of electricity have significantly aggravated power shortages in Asian countries. In Pakistan, for example, 28% of the total electricity production is lost in transmission and distribution. Indian utilities suffered losses of about 23% during 1989-90. Long-distance electricity transmission from hydropower or pithead coal-fired power plants faces difficulties.

Financing. It is estimated that an additional power capacity of about 200 GWe is needed in Asia over the next decade. This calls for an investment of at least US $500 billion in power systems. Because most power projects in Asian countries have been domestically regulated, the governments are increasingly recognizing that they can no longer afford to foot the bill themselves. As a result, a number of Asian countries, such as the Philippines and Malaysia, are promoting privatization within the energy sector, and encouraging the private sector to invest in power projects. Direct foreign investment and joint venture schemes are other financing approaches pursued by some governments (e.g., China) to get foreign capital for large-scale and advanced power projects.*

Nuclear power experience in Asia

In Asia, 70 nuclear power plants were connected to electric grids and 21 were under construction at the end of 1992. All four of the power

*The features and problems concerning the financing of nuclear power projects in developing countries are discussed in greater detail in the IAEA's recent publication, *Financing Arrangements for Nuclear Power Projects in Developing Countries*, Vienna (1993).

reactors which started construction in the world during 1991-92 are located in Japan and the Republic of Korea. Moreover, all new reactors (more than 10) that are expected to start construction worldwide during 1993 are located in Asia. *(See table.)*

The development of nuclear power in Asian countries and regions can be grouped as follows:

● The first group includes Japan, the Republic of Korea and Taiwan, China. In order to ensure energy security and reduce dependence on imported fossil fuels, long-term consistent nuclear power programmes were established and have been successfully implemented there. In Japan, Republic of Korea, and Taiwan, China, the nuclear shares of total electricity generation reached 27.7%, 43.2% and 35.4% in 1992, respectively. To a significant degree, the industrial infrastructures have been built up and there is a growing technological self-reliance in the field of nuclear power. In Korea, the degree of technological self-reliance is expected to reach 95% by the time Yonggwang units 3 and 4 start commercial operation in 1995. On economic grounds, studies show that the use of nuclear power for electricity generation is cheaper than using fossil fuels in Japan and is competitive with coal in Korea.

● China and India form the second group. The rapid population growth and economic development call for significant expansion of electrical generation capacity. Heavy dependence on coal-fired power generation results in serious environmental pollution in many areas. Nuclear power has been introduced in order to abate the impacts and mitigate power shortages. Both countries have established capabilities in the nuclear field based on indigenous technology and resources, and they have the strong potential for further nuclear power development. Studies made in these countries show that nuclear power would be competitive in the industrial regions, which are far away from cheap coal reserves and now burdened by environmental pollution. India's tenth power plant, Kakrapar-1, has gone into commercial operation. Most Indian reactors are pressurized heavy water reactors (PHWR) of domestic design. China's first indigenous nuclear power plant (Qinshan) achieved full operation in August 1992. The first unit of the imported Daya Bay nuclear plant started up in July 1993 and the second unit is expected to start up in 1994. Nuclear projects are planned for several provinces of China.

● The third group includes the Philippines, Pakistan, and Iran. Each has had difficult experiences in the establishment of nuclear power programmes. Pakistan has a 125-MWe PHWR, which is over 20 years old and has had rather low operating performance. The Bataan nuclear power plant (a 620-MWe pressurized water reactor) in the Philippines was completed in 1986, but the government has declared that it will not be put into operation. The construction of a nuclear power plant in Iran has been stranded for a long time. The three countries, however, have not abandoned the pursuit of their commitment to nuclear power deployment. Construction work on Pakistan's second nuclear power plant (a 300-MWe pressurized water reactor supplied by China) started in August 1993. Iran is negotiating with China and Russia to buy nuclear power plants. In July 1993 the President of the Philippines ordered the formulation of a comprehensive nuclear power programme.

● The fourth group consists of a number of Asian countries, including Indonesia, Thailand, Malaysia, Democratic People's Republic of Korea, Viet Nam, Turkey, and Bangladesh. The governments all have announced their intentions to develop nuclear power. In Indonesia, a feasibility study for a 600-MWe nuclear plant in the densely populated and fast developing region of Java is expected to be completed in 1996. The aim is towards the operation of Indonesia's first nuclear power plant by 2003. In Thailand, a tentative plan to construct 6 GWe of nuclear capacity with six units is expected to be submitted for government approval and a 3-year commercial feasibility study is foreseen; the first two units are scheduled to be commissioned in 2006. In Turkey, Atomic Energy of Canada Limited (AECL) has submitted a comprehensive proposal to the Turkish authorities for a 700 MWe reactor at the Akkuyu site.

Nuclear power prospects

Planning of nuclear power projects. Ambitious plans for significantly increasing nuclear power capacity are evident throughout most of Asia. The latest orders for nuclear power plants in the world all came from Asian countries.

In Japan, nuclear energy has become an economical and stable energy source, and its role has been clearly defined for the long term. Japan's electric utilities have announced a plan for starting construction on 10 new nuclear units within the next 2 years. A report by the Ministry of Trade and Industry has called for an additional 40 GWe to be added by 2010, doubling Japan's present nuclear capacity.

The Republic of Korea is planning to build 18 more nuclear units over the 1991-2006 timeframe, with the total nuclear generating capacity scheduled to reach 23 GWe by the year 2006.

Nuclear power status in Asia at the end of 1992

Country	Reactors in operation		Reactors under construction		Nuclear share of electricity	*Reactors planned*		
	No. of units	Total MWe	No. of units	Total MWe	(%)	No. of units	Total MWe	Year in operation
China	1	288	2	1812	0.1	12	8400	2005
India	9	1593	5	1010	3 3	16	3100	2000
Indonesia						1	600	2003
Iran			2	2392			600-2600	2010
Japan	44	34 238	9	8129	27 7		72 500	2010
Korea Rep. of	9	7220	3	2550	43 2	27	23 000	2006
Malaysia						1		2002
Pakistan	1	125			1.2	2	425	1999
Philippines			1	620**			620-1500	2010
Thailand						2	2000	2006
Turkey						1	700	2000
Viet Nam							800-1200	2010
Asia total*	70	48 354	22	16 513				
World total	424	330 651	72	59 720	16.7			

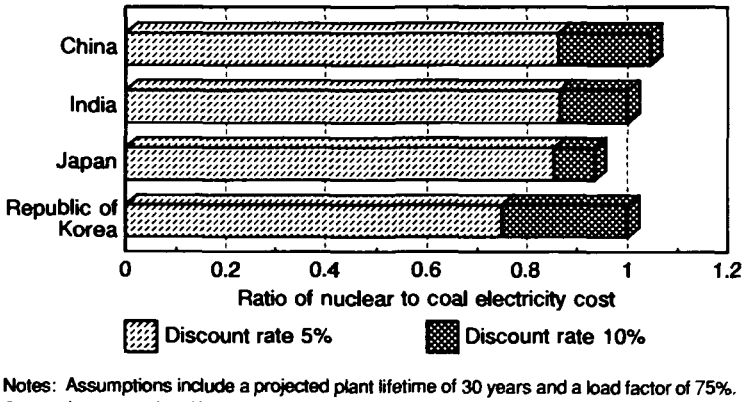
*The totals includes 6 units, 4890 MWe in operation, in Taiwan, China (nuclear share 35 4% of total electricity generation)
**Mothballed plant
Sources IAEA PRIS Information for planned reactors was derived from selected reports on national plans

In China, nuclear power is clearly gaining in importance in the national energy development strategy. Up to now eight provinces have been active in constructing plants or in site and feasibility studies for new nuclear plants. The review of the preliminary design for the second phase of the Qinshan project (two 600-MWe pressurized water reactors) was approved in November 1992. Preparations and negotiations with foreign suppliers have begun for the second phase of the Daya Bay project (two 900-MWe pressurized water reactors). An agreement was signed by China and Russia for construction of two units of WWER design (two 1000-MWe plants) in Liaoning. Additionally, Jiangxi province is preparing to build a 600-MWe nuclear plant, and Hainan Island has proposed to build two 350-MWe pressurized water reactors.

In Taiwan, China, Taipower has invited bids for its fourth nuclear power plant (two 1000-MWe light water reactors). The plant is expected to be completed by the year 2000.

India plans to build as many as 15 more nuclear power reactors in the next 10 years to ease the power crisis in the country. If budgetary resources are available, Pakistan intends to buy a second 300-MWe pressurized-water reactor from China. In its long-term planning, Indonesia has stated its intention to start a nuclear power programe, while in Thailand, 6 GWe of nuclear capacity has been proposed.

Economic competitiveness of nuclear and coal-based electricity in Asian countries



Notes: Assumptions include a projected plant lifetime of 30 years and a load factor of 75%.
Source: Joint study of the IAEA and the Nuclear Energy Agency and International Energy Agency of the Organization for Economic Co-operation and Development (1993).

Economic competitiveness. The economic competitiveness of nuclear power with conventional baseload electricity generation depends on a number of country-specific and local factors. These include the local prices of fuels, environmental protection and other regulatory requirements, and the required capital return rate or discount rate.

Nuclear power is competitive with conventional electricity generation in countries with strong electric grids and lack of indigenous energy resources, such as Japan and the Republic of Korea. Nuclear power is also competitive in regions with strong economic growth which are distant from large coal or gas fields or cheap hydropower. This includes the coastal regions of China, West and South India, and some regions of the third and fourth groups of countries

referred to above. Studies made by four Asian countries (China, India, Japan, and the Republic of Korea) have shown that nuclear power would be, in most cases, the cheapest option for generating electricity from projected plants which are scheduled to start operation around the year 2000.

Technology development. Nuclear power developments in Asian countries are promoting the technological development of national nuclear industries. The world's first advanced boiling water reactor is being built in Japan. Significant development of Candu PHWRs will be gained by replication in the Republic of Korea. China is developing an indigenous reference plant, the AC 600-MWe PWR, characterized by advanced functions and passive safety features. India is considering the utilization of thorium for nuclear electricity production because of its limited uranium resources. Due to their small electric grid systems and the limited availability of capital, many Asian countries also are attractive markets for deployment of improved small and medium power reactors.

Fast breeder reactors (FBRs) are being actively developed in Asia, with an eye towards nuclear's long-term contribution. At Monju, Japan's pilot fast breeder reactor, first criticality is expected to be achieved in 1994. India plans to make a detailed review and finalize the design of a 500-MWe prototype fast breeder reactor in the next 2 years. The engineering preparation for a pool-type experimental FBR (65 MWth) has been implemented in China.

Addressing issues and needs

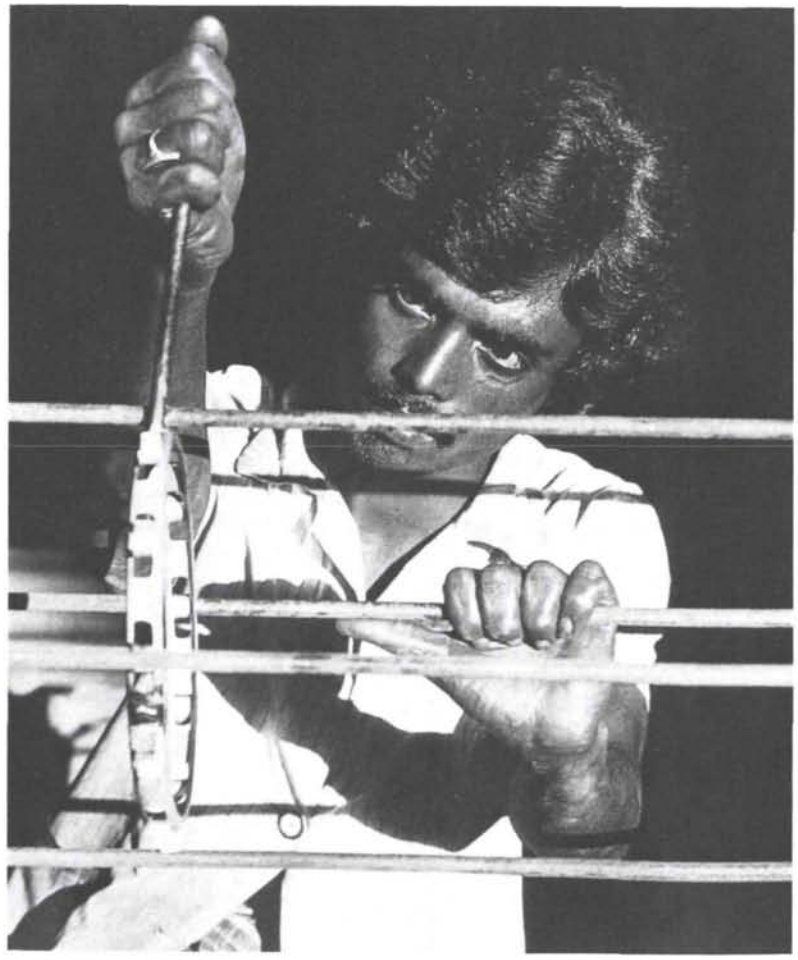
The high capital costs of nuclear power make it difficult to implement ambitious plans for nuclear power in many developing countries which lack investment capital. Financing is a key factor for expanding nuclear power in China and India. A number of Asian countries are trying to attract private and foreign investment in nuclear power plants.

The extent of national participation is dependent on the locally available industrial infrastructure. A strong participation of local industry may lead to initially higher costs for a small-scale nuclear programme, but could lead to lower costs for a long-term, large-scale nuclear power programme.

Nuclear power deployment is technologically demanding in terms of human resources. Highly qualified staff are vital for design, equipment fabrication, construction, management, and operation of nuclear power plants in order to achieve good plant performance, high levels of safety, and competitive economics. Other factors for consideration include the selection of suitable sites for power plants and the permanent disposal of radioactive waste, two areas which have raised public concern about nuclear energy.

The IAEA offers comprehensive assistance to support countries interested in electric system expansion planning, nuclear power project feasibility studies, plant siting, human resources development, project management, plant engineering, and safety assessments, for example. Various technical assistance projects have been carried out for Asian nuclear power development.

Throughout this decade, Asia is expected to continue its rapid economic growth with increasing demand for electricity. Nuclear power could play an increasingly important role in sustainable economic development in the region, providing particular benefits in areas of environmental protection and energy security. It is estimated that as many as 90 to 100 nuclear units could be connected to Asian grids by the year 2000, with further development of nuclear power foreseen after the turn of the century. ❐



A technician working on a power transmission line in Bangladesh. ***(Credit: ADB)***