Nuclear power beyond Chernobyl: A changing international perspective

Nuclear power's development has slowed over the past 10 years but steady growth is projected well into the next century

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Statistics show that nuclear power has become an important energy source in many countries since its introduction four decades ago. In the 1960s, the industry was convinced that nuclear power represented the solution to cheap and reliable energy supply, and programmes were eagerly pursued worldwide. As a result, the construction of nuclear power plants expanded rapidly through the 1970s. According to data in the IAEA's Power Reactor Information System (PRIS), by 1980 nuclear power production had increased to 692.1 terawatt-hours (TWh), contributing 8.4% of total electricity generation. *(See figures, next page.)* This represented an almost ninefold increase since 1970, and an average annual growth of 24% over the decade.

Since the 1980s, the expansion rate has dropped markedly even though significant new nuclear electricity capacity is still added each year. In the period 1980-85, nuclear electricity generation increased to 1402 TWh, corresponding to an average annual growth of 15.2% in generation; in the next half decade, during 1985-90, it increased to 1913 TWh, yielding an annual growth of 6.4%. In the period 1990-94, it increased to 2130 TWh, corresponding to a growth of about 2.8% per annum. The five largest producers in 1994 were the United States (639.4 TWh), France (341.8 TWh), Japan (258.3 TWh), Germany (143.0 TWh), and Canada (101.7 TWh).

Worldwide, the nuclear option today accounts for about 17% of the total electricity produced. In altogether 14 countries (as well as in Taiwan, China), one-quarter or more of the electricity is generated by nuclear power plants. Nuclear power accounts for some 40% or more in eight countries: Belgium, Bulgaria, France, Hungary, Lithuania, Slovakia, Sweden, and Switzerland. *(See the International Data File section, page 53.)*

By the end of 1995, a total of 437 units with a generating capacity of over 343 gigawatts-electric (GWe) were in operation in the world, and 39 units with a generating capacity of over 32 GWe were under construction. The total accumulated operating experience of the operating plants amounts to more than 6637 reactor years, or an average operating period per plant of about 15 years. Substantial operating experience has also been gained by plants that have now been shut down, and factoring in these plants yields a total of more than 7700 reactor years. In other words, by now, nuclear energy has acquired a strong position in the electricity generation sector as a mature technology.

Impact of the Chernobyl accident

Recent development trends could give the impression that nuclear power's slower rate of growth after the 1985-90 period is mostly due to the Chernobyl accident, which occurred in April 1986. Actually, other factors were at work as well, and overall Chernobyl's impact varied around the world.

One factor has been the rate of electricity growth, which in many countries declined during the past decade and influenced decisions about capacity additions throughout the electricity sector. Since the construction of a nuclear plant takes 5 to 8 years to complete, with a lead time (after contract) of 1 to 2 years, any observable indication of Chernobyl's direct impact over the past decade would be hard to discern.

Still, the accident did have immediate consequences in some countries. In countries operating Chernobyl-type reactors, the operation of the plants was carefully checked and a number of restrictions were imposed. Public opposition also caused other types of plants outside these coun-

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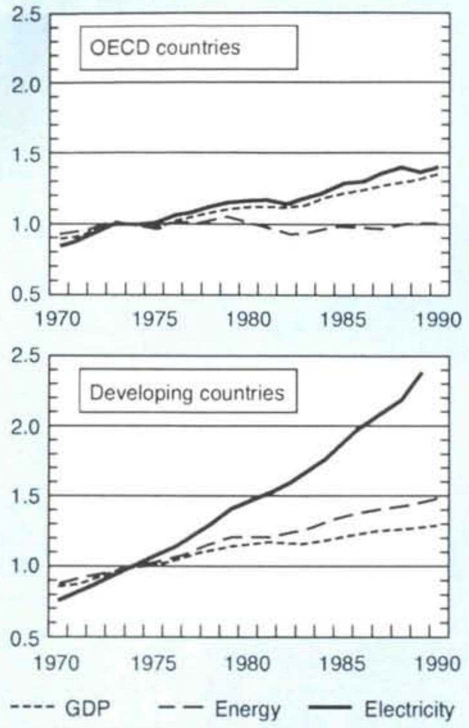
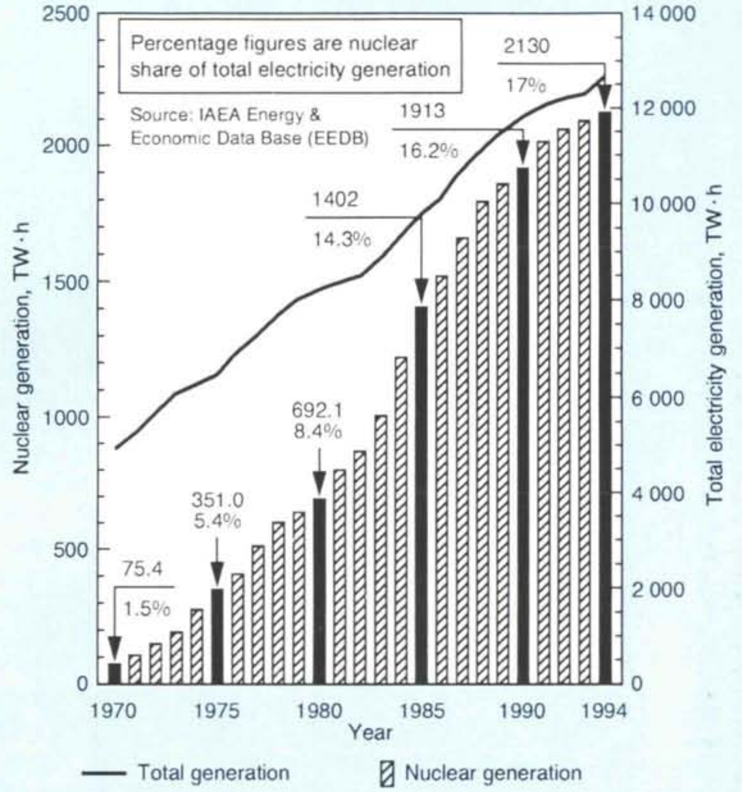
Growth Trends for Gross Domestic Product (GDP), Energy, and Electricity

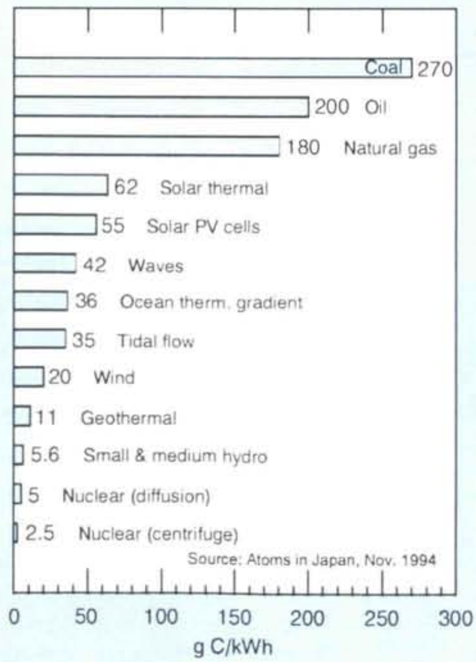
(per capita values, normalized to 1 in 1974)



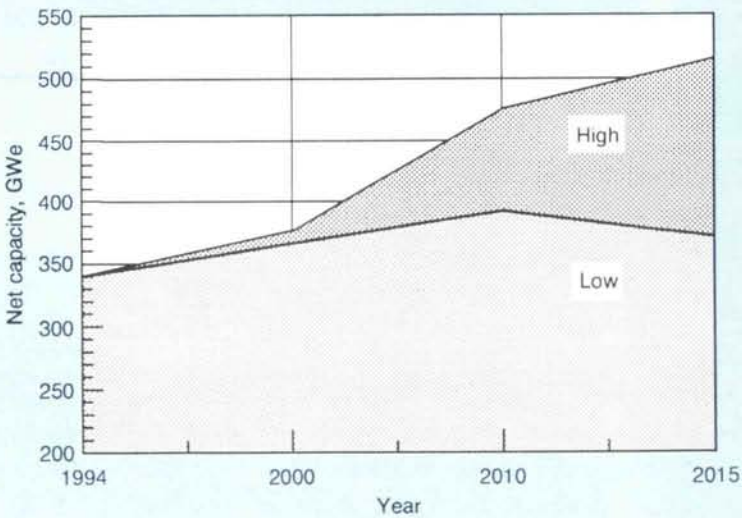
Growth of Nuclear Electricity Generation Since 1970



CO_2 Emission Factors from the Full Energy Chain of Different Power Sources



Worldwide Nuclear Power Outlook up to 2015



Nuclear power's growth has slowed markedly over the past two decades, though steady development continues. Environmental concerns are driving renewed interest in nuclear-generated electricity, a low CO_2 option.

tries to shut down for a period of time. In Italy, the Caorso plant was taken out of service indefinitely and construction of the Montalto di Castro plants was stopped following a referendum in the wake of the accident, and in both Finland and the Netherlands plans for new nuclear power plant projects were mothballed.

Generally in Europe, the Chernobyl accident is one of the reasons that increases in nuclear deployment have been brought more or less to a complete halt; politicians do not dare to promote nuclear power as a safe and clean energy source, and utilities are afraid of the financial risks with respect to the economic consequences of a major nuclear accident. Besides, the economies of the European countries have been growing at a very slow rate, if growing at all, and the rate of growth in overall energy demand has been very small. On the other hand, recent studies have shown that the picture is likely to change. Electricity consumption continues to rise with economic growth, even when total energy consumption is decreasing. In a few years time more generating capacity will be needed in many countries, and chances are that some of this additional capacity will be nuclear power plants.

In regions of Asia, the situation is different; the rate of growth in energy demand is very high and nuclear is seen as an attractive option. Many countries in these regions have ambitious programmes for deployment of nuclear power in the next decades, and vendors worldwide are anticipating a revitalization of the nuclear market.

Advanced nuclear power plant designs

In a number of countries, great emphasis is being placed on the development of advanced nuclear power plant designs. These new generations of nuclear power plants have been, or are being, developed by building upon experience and applying lessons learned from existing plants. Hence, the new, advanced designs are anticipated to become even more safe, economic, and reliable than their predecessors.

The advanced designs generally incorporate improvements of the safety concepts, including, among others, features that will allow operators more time to perform safety actions, and that will provide even more protection against any possible releases of radioactivity to the environment. Great attention is also paid to making new plants simpler to operate, inspect, maintain, and repair, thus increasing their overall reliability and economy.

Advanced designs comprise two sub-categories: evolutionary and developmental designs. The first encompasses direct descendants from predecessors (existing plant designs) that feature improvements and modifications based on feedback of experience and adoption of new technological achievements. They also take into account possible introduction of some new features, e.g., by incorporating passive safety functions. Evolutionary designs are characterized by requiring, at the most, engineering and confirmatory testing prior to commercial deployment. Developmental designs consist of those that deviate more significantly from existing designs, and that consequently need substantially more testing and verification, probably including also construction of a demonstration plant and/or prototype plant before large-scale commercial deployment.

Advanced designs under development comprise three basic types: water-cooled reactors, utilizing water as coolant and moderator; fast reactors, using liquid metal, e.g. sodium, as coolant; and gas-cooled reactors, using gas, e.g. helium, as coolant and graphite as moderator.

Most — about 75% — of the nuclear power reactors in operation are water-cooled reactors, and most of the advanced designs are, too. They are of two basic types: light-water reactors (LWRs) with ordinary water as moderator, and heavy-water reactors (HWRs). The LWRs are in turn subdivided into boiling and pressurized water reactors (BWRs and PWRs).

Some examples of large evolutionary advanced LWRs are: the ABWR of General Electric, United States; the APWR of Westinghouse, United States and Mitsubishi, Japan; the BWR-90 of ABB Atom, Sweden; the EPR of Nuclear Power International (NPI), a joint company of Framatome in France and Siemens in Germany; the SWR (or BWR) 1000 of Siemens; the System 80+ of ABB Combustion Engineering, United States; the WWER-1000 (V-392) of Atomenergoproject and Gidropress, Russia; and the KNGR of KEPCO and KAERI, the Republic of Korea. Among the medium-size ALWRs, five typical designs are the AP-600 of Westinghouse, United States; the AC-600 of China National Nuclear Corporation, China; the MS-600 of Mitsubishi, Japan; the SBWR of General Electric, United States; and the WWER-640 (V-407) of Atomenergoproject and Gidropress, Russia. Many of the large- and medium-size designs are already available for commercial deployment, or will be within a number of years.

The situation for developmental designs — such as ISIS of Ansaldo, Italy; PIUS of ABB Atom, Sweden; SPWR of JAERI and IHI, Japan; and VPBER-600 of OKBM, Russia — is more uncertain. This is due to the need for experimental verifications and associated financing burdens.

Typical examples of advanced HWRs under development are the advanced Canadian designs — Candu-3 (of about 450 MWe), the Candu-6 (currently of about 680 MWe), and the Candu designs (of 900-1100 MWe) of AECL, Canada — and the improved Indian PHWR design (of about 500 MWe).

Liquid metal-cooled fast reactors (LMFRs), or breeders, have been under development for many years in a number of countries. The design, construction, and operation of several plants, such as the BN-600 in Russia, the 1200-MWe Superphenix in France, and the 280-MWe Monju in Japan, has provided extensive experience of more than 200 reactor years for further improvements. The fast reactors use "fast" neutrons for sustaining the fission process, and they actually produce fuel as well as consume it; plutonium breeding allows fast reactors to extract sixty times as much energy from uranium as thermal reactors do. Their capability of producing fissile material may become indispensable in the longer term if the deployment of nuclear power is increased substantially in the decades to come. Fast reactors may also contribute to burning of plutonium and to reduction of the required isolation time for high-level radioactive waste by burning of long-lived transuranic radioisotopes.

The further development of fast reactors focuses on improving plant safety and economy, and on improvements of fuel burnup and fuel recycling technology to reduce the amounts of radioactive waste. Examples of development concepts are the BN-800M in Russia, the DFBR in Japan, the PFBR in India, the advanced European EFR, and the LMR developed by General Electric in the United States.

Gas-cooled reactors have been in operation for many years. In the United Kingdom, nuclear electricity is mostly generated in CO_2-cooled Magnox and Advanced Gas-Cooled Reactors (AGRs). Other countries also have pursued development of high-temperature reactors (HTGRs) with helium as coolant, and graphite as moderator. Prototype or demonstration plants have been built, without complete success, however. The inert helium gas and a special fuel design enable these plants to operate at temperatures considerably above those in water-cooled reactors; hence, they can supply steam for conventional steam turbine generators at much higher temperature (and pressure), or high-temperature process heat for special applications.

Further HTGR development concentrates on improved plant performance and life extension studies. In particular, much effort is devoted to the direct gas-turbine cycle which may yield very high thermal efficiency and low energy cost. A demonstration plant for testing of high temperature process heat applications is under construction in Japan, and construction of a test reactor has begun in China.

Prospects for nuclear power

Nuclear power alone will not ensure secure and sustainable electricity supply worldwide, nor will it be the only means of reducing greenhouse gas emissions, which continue to be a major environmental concern. But it has a key role to play. Studies of greenhouse gas emissions from different energy chains for electricity generation indicate that nuclear power is one of the cleaner options. *(See graphs.)*

A prerequisite for realizing the necessary revival of the nuclear option is that the technical and economic performance of nuclear power plants must improve. At the same time, plant safety must be further enhanced and the issues of waste management and disposal must be more satisfactorily addressed.

At the present time, nuclear power is among the cheapest sources of electricity generation in many countries. Its competitive margin has been reduced, however, by low fossil fuel prices and increases in nuclear power plant capital costs, which are very much due to long construction and licensing lead times. Rising market prices of fossil fuels, in particular gas, and increased capital and operating costs of fossil fired units due to the required addition of abatement systems for environmental reasons may reverse this trend in the coming decade. The economic advantage of nuclear power can further be increased by the efforts of reactor designers to reduce capital costs by streamlining the reactor concepts, reducing the amount of material required, and shortening the construction times. Substantial progress has been achieved in this regard and additional gains are expected through the deployment of advanced reactors.

Financing nuclear power plants will remain a key issue, especially in developing countries. Technology adaptation, the development of small- and medium-size reactors, and the implementation of new financing approaches may alleviate funding constraints and facilitate a broader deployment of nuclear power.

Nuclear power projections beyond 2000

Projecting nuclear power development is a somewhat difficult exercise. A number of factors can influence policies and decision-making, and the implementation of programmes cannot be assessed with certainty.

Up to the year 2000, the installed nuclear capacity worldwide will grow to between 367 GWe and 375 GWe, compared to 340 GWe in 1994, according to IAEA estimates. Since all the units to be commissioned by the turn of the century are already under construction, the range of uncertainty reflects potential delays in construction and licensing. New nuclear units will be connected to the grid mainly in Asia, while in Western Europe and North America the installed nuclear capacity will remain practically unchanged. In Eastern Europe, although some of the units under construction will be completed, the economic transition will delay significantly the implementation of nuclear programmes in most countries.

After the turn of the century, the range of uncertainty regarding nuclear power development is wider, owing to a number of technical, economic, environmental, and policy factors. The low and high projections for nuclear generating capacity developed by the IAEA up to 2015 are based upon a review of nuclear power projects and programmes in Member States. They reflect contrasting but not extreme underlying assumptions on the different driving factors that have an impact on nuclear power deployment. These factors and the ways they might evolve vary from country to country. Consequently, the IAEA projections do not reflect the whole range of possible futures from the lowest to the highest feasible, but provide a plausible range of nuclear capacity growth by region and worldwide.

In the low case, the current barriers to nuclear power deployment are assumed to prevail in most countries during the coming two decades. Economic and electricity demand growth rates remain low in industrialized countries. Public opposition to nuclear power continues, and environmental concerns, such as the risk of global climate change, do not become strong driving factors in energy policies to switch from fossil to nuclear energy. Institutional and financing issues prevent the implementation of previously planned nuclear programmes, in particular in countries in transition and in developing countries, and there is no drastic enhancement regarding nuclear technology adaptation and transfer, nor financial support to developing countries for the implementation of nuclear power projects.

Under these rather pessimistic assumptions, most of the nuclear units under construction would be completed but new nuclear units would be ordered only in the countries where nuclear power is a major component of electricity generation mixes, such as France, Japan, and the Republic of Korea. Owing to the large number of units that would be shut down at the end of their scheduled operating lifetime, the total nuclear capacity in the world would start to decrease after 2010 and would be similar in 2015 to that in 2000, i.e., at some 370 GWe. The share of nuclear power in world electricity supply would decrease from about 17% at present to some 13% in 2015.

The high case reflects a moderate revival of nuclear power deployment, that might result in particular from a more comprehensive comparative assessment of the different options for electricity generation, integrating economic, social, health, and environmental aspects. This case assumes that some policy measures would be taken to facilitate the implementation of these programmes, such as strengthening of international co-operation, enhanced technology adaptation and transfer, and establishment of innovative funding mechanisms. Based on these assumptions, the total installed nuclear capacity worldwide would reach some 515 GWe in 2015 and the share of nuclear power in total electricity generation would be some 15%.

In both the low and high cases, the production capabilities of the world nuclear industry would exceed the demand for new reactors. A higher rate of nuclear power development would be technically feasible and economically viable in a number of countries. However, a substantive revival of nuclear power programmes would require policy measures, including a removal of the *de facto* moratoria in several countries and the introduction of mechanisms for providing funding support to nuclear projects in developing countries, which seem unlikely to be implemented in the short term.

Other applications of nuclear energy

Today, only a few nuclear plants are being used for non-electric applications (with a total capacity of only 5 GWth to supply hot water and steam). The potential market for applications of nuclear energy in the non-electric energy sector may be quite large, however. About 30% of the world's primary energy consumption is used for electricity generation, about 15% is used for transportation, and the remaining 55% is converted into hot water, steam, and heat. Non-electric applications include desalination, hot water for district heating, and heat energy for petroleum refining, for the petrochemical industry, and for the conversion of hard coal or lignite.

For non-electric applications, the specific temperature requirements vary greatly. Hot water for district heating and heat for seawater desalination require temperatures in the 80° to 200°C range, whereas temperatures in the 250° to 550°C range are required for petroleum refining processes. The use of heat for enhancing heavy oil recovery can be applied by the method of hot water or steam injection. The temperature and pressure conditions required for heavy oil recovery are highly dependent on the geological conditions of the oil field; the temperature requirements range up to 550°C and above. Oil shale and oil sand processing requires temperatures ranging from 300° to 600°C, and processes used in the petrochemical industry require higher temperatures, in the range of 600° to 880°C. Still higher temperatures (up to 950°C) are needed for refining hard coal or lignite (for example, to produce methanol for transportation fuel), and temperatures of 900° to 1000°C are necessary for the production of hydrogen by water splitting.

Water-cooled reactors can provide heat up to about 300°C, and liquid-metal-cooled fast reactors produce heat up to about 540°C. The gas-cooled reactors can provide even higher temperatures, about 650°C for advanced gas-cooled, graphite-moderated reactors (AGRs), and up to 950° to 1000°C for high-temperature gas-cooled reactors (HTGRs).

There is considerable incentive to utilize the capability of nuclear plants to provide co-generation of electricity, steam, and heat for residential and industrial purposes. Experience in co-generation with water-cooled reactors has been gained in the Russian Federation, China, Canada, the Czech Republic, Slovakia, Switzerland, Germany, Hungary and Bulgaria. One of the largest uses of nuclear process steam is at the Bruce Nuclear Power Development Facility in Ontario, Canada, where the Candu PHWRs are capable of producing 6000 MWe of electricity as well as process steam and heat for use by Ontario Hydro and an adjacent industrial energy park.

An important milestone in the development of high-temperature nuclear process heat was reached in March 1991 with the start of construction of the HTTR (High Temperature Engineering Test Reactor) at the Oarai Research Establishment of the Japanese Atomic Energy Research Institute. It will be the first nuclear reactor in the world to be connected to a high-temperature process heat utilization system.

Nuclear power in developing countries

Most nuclear power plants are located in industrialized countries, but a number of developing countries also are relying on the nuclear power option. At the end of 1995, there were 73 nuclear units (or about 16% of the total number in the world) with a net capacity of close to 45 GWe (about 13% of total worldwide capacity) in operation in developing countries. The accumulated operating experience of these plants amounts to 850 reactor years, corresponding to an average of 11 years of operation per plant.

This means that nuclear power already is an established technology in a number of developing countries. The deployment of nuclear power is also expected to expand substantially in the next decade. It can be noted that more than half of the 39 units reported as "under construction" in 1995 were being built in developing countries.

The world's energy demands are expected to rise significantly in the coming decades. The world population has nearly doubled over the last three decades and will continue to increase. Forecasts are that by the year 2020 there will be about eight billion people living on this planet, with some 90% or more of the population increase taking place in developing countries. In these countries, electricity consumption *per capita*, which may be used as an indicator of standard of living, is very low, about one or two orders of magnitude below industrialized countries.

The high cost of building nuclear power plants, however, and financing constraints have become major hurdles for many developing countries. For countries with an existing infrastructure, established nuclear power programmes, and an indigenous manufacturing capability, the situation is not too bad; they need only to import special components, equipment and know-how from abroad, with a corresponding limited spending of foreign currency.

In most developing countries, a suitable infrastructure and manufacturing capability is not available. They generally also have a currency that is not convertible, which means that when they buy most of the plant equipment from abroad, they must depend heavily on loans from foreign banks or institutions.

In this context, it may be noted that when constructing the first nuclear power plant a preferable approach appears to be having a "turnkey" delivery, including a technology transfer programme. In that way, the possibilities of making the first plant project a success, actually a matter of paramount importance for the acceptability of a nuclear programme, would be the best. Additionally, the transfer of technology will enable the country to gradually develop its own capabilities, and successively increase the domestic participation in subsequent nuclear power plant projects.

Some developing countries, such as China, India, and the Republic of Korea, have ambitious programmes for deployment of nuclear power, and are also actively pursuing development of their own reactor designs. China has three nuclear units in operation, of which one is of own

Role of the IAEA in Nuclear Power Development

Advanced Reactor Development. The early development of nuclear power was conducted to a large extent on a national basis. However, for advanced reactors, international co-operation is playing a greater role, and the IAEA promotes international co-operation in their development. Especially for designs incorporating innovative features, international co-operation can play an important role for pooling resources and expertise in areas of common interest to help meet the high costs of development.

The Agency's programme in nuclear power technology development promotes technical information exchange and co-operation between Member States with major reactor development programmes. It offers assistance to Member States with an interest in exploratory or research programmes, and publishes reports which are available to all Member States interested in the current status of reactor development. Activities are focused on key issues (for example safety concerns, high capital costs, complex and expensive operating procedures) which currently hinder further introduction of nuclear power.

IAEA activities in the development of water-cooled, liquid-metal-cooled, and gas-cooled reactors are co-ordinated by three international working groups (IWGs) which are committees of leaders in national programmes in these technologies. Each IWG meets periodically to serve as a global forum for information exchange and progress reports on national programmes, to identify areas of common interest for collaboration, and to advise the IAEA on its technical programmes and activities. This regular review is conducted in an open forum in which operating experience and development programmes are frankly discussed. Smaller specialists' meetings are convened to review progress on selected technology areas in which there is a mutual interest. For more general participation, larger technical committee meetings, symposia, or workshops are held. The IWGs sometimes advise the IAEA to establish co-operative programmes in areas of common interest in order to pool efforts on an international basis. These co-operative efforts are carried out through co-ordinated research programmes (CRPs). CRPs are typically of a duration of 3 to 5 years and often involve experimental activities. Such CRPs allow a sharing of efforts on an international basis to develop technology at a lower cost than would be required with separate national efforts, and to benefit from the experience and expertise of researchers from the participating institutes.

Nuclear Power Plant Personnel Training & Qualification. Agency activities in this area have expanded greatly since 1993. The main focus is the introduction and use of a systematic approach to training (SAT) for plant personnel to enhance their qualification and competence and thus the safety and reliability of plant operation and maintenance. Regulatory bodies in a number of Member States mandate or strongly recommended the SAT approach to the training of nuclear power plant personnel.

An International Working Group on Nuclear Power Plant Personnel Training and Qualification was constituted in 1994 to provide advice concerning IAEA activities in this area and to promote global co-operation. A new type of IAEA assistance on personnel training has been introduced in the form of the Training Advisory Service (TAS). On request from a Member State or nuclear power plant, the IAEA organizes a TAS, which comprises training experts from various countries who would provide technical advice and assistance on all aspects of training, including the exchange of experience and good practices.

Nuclear Power Plant Project Management. The IAEA provides assistance to requesting Member States in a variety of areas related to the use of nuclear power for safe and economic electricity generation. This assistance is directed to national authorities, operating organizations, and the industrial infrastructure that supports the planning and execution of nuclear power project.

An important objective is to assist developing Member States in achieving self-sufficiency in the systematic development and improvement of a wide range of infrastructural facilities, including organizational structures and their management, transfer of tools and methodologies for project management, and the feedback of construction experience from successful project execution.

No less important is the problem of providing qualified human resources to plan, regulate, and implement the nuclear power programme. Thus, programmes are being supported with the objective of creating an independent national training infrastructure that meets the needs of the nuclear industry. To this effect, ten projects for nuclear power programme implementation are being put into service in eight countries in regions of the Middle East, Europe, Asia and the Pacific.

In order to complement assistance provided under individual projects, topical training courses, workshops, and seminars are held on subject matters selected for their relevance to country specific needs and requirements. At the international level major training courses are offered periodically for participants from all regions. These courses are designed to represent an effective transfer of technology that helps create a base of trained personnel in developing countries. They cover subjects such as strengthening project management, quality assurance in nuclear power plant operation and maintenance, qualification of nuclear power plant operations personnel, and control and instrumentation in nuclear power plants.

design, and has ordered another two 950-MWe units from abroad. It also plans construction of a WWER-1000, and is discussing construction of Candus with AECL of Canada. The near-term programme includes serial production of a 600-MWe version of the indigenous PWR design that is in operation at Qinshan, and further development of that type; construction of a heating reactor of its own design at Daqin; and construction of a high temperature test reactor.

India has 10 plants in operation of which six are PHWRs of own design, and another four are under construction. Development activities are concentrated on a 500-MWe PHWR and a 500-MWe fast, sodium-cooled breeder reactor.

The Republic of Korea has 11 units in operation, all supplied by foreign vendors. With its latter units, the country has entered a new era, bringing on line the first of a series of plants based on the System 80 of ABB Combustion Engineering for which more and more design, engineering, and equipment are supplied by Korean companies. Five plants of this series and of another type are under construction, and a further 11 plants are planned for the period up to 2006. Development also has begun on the next generation reactor, with operation targeted for 2006.

Some other developments should also be noted: the supply to the Democratic Peoples Republic of Korea of two PWR plants of Korean Standard Nuclear Power Plant; Indonesia's rather firm plans on introduction of nuclear power within some years; Thailand's interest in nuclear power; the Islamic Republic of Iran's desire to get support for completing the Bushehr units; Pakistan's construction of one 300-MWe PWR and its discussions on the possibilities of having a second such unit built; Morocco's desire to start a feasibility study on desalination of seawater using nuclear-supplied heat; and Egypt's plans on utilization of nuclear power.

In Eastern Europe, Armenia has restarted one of its nuclear plants; the Czech Republic has two units under construction; Romania has four units under construction; the Slovak Republic has four units under construction, and Ukraine has two (with plans for six) units under construction.

In Latin America, Argentina and Brazil each have one unit under construction. Argentina is also developing its own nuclear reactor designs. Mexico has two plants in operation, but no firm plans for further construction; in the early 1980s, it had a very ambitious programme for nuclear power development that had to be abandoned for financing reasons. It can also be noted that Venezuela has been discussing utilization of nuclear power plants for heat and electricity generation; the heat is intended for improving the heavy oil extraction along the Orinoco river.

Challenges and prospects

Prospects for nuclear power should be assessed in the context of growing electricity demand and greater awareness of environmental issues. Nuclear power alone will not solve all the problems, but it will form part of the answers.

Over the near term, nuclear power projects will be pursued mostly in Asian countries, including China, Japan, and the Republic of Korea. In many other regions of the world, safe and reliable operation of nuclear power plants, convincing solutions to high-level nuclear waste storage and disposal, and a predictable licensing process are essential prerequisites for the revival and expansion of nuclear power.

Today, energy consumption trends reflect the important role that electricity plays in modernization efforts and in total energy use and efficiency improvements. Also increasingly evident is that full participation in the information and communication age requires reliable sources of electricity. Studies have shown that there is a distinct correlation between the trends of electricity consumption and national economic output in a wide range of countries. From 1960 to 1990, the share of electricity in global energy consumption has grown from 17% to 30% and the annual consumption of electricity *per capita* has almost tripled (from 765 to 2225 kWh per person). Still, two billion people in the world do not have access to electricity in their homes.

For years ahead, it is quite obvious that *per capita* consumption of electricity in developing countries will have to increase substantially to sustain economic growth and improve standards-of-living. The accelerating movement toward urbanization, which allows easier access to electrical distribution systems, together with the electrification of rural areas, will also contribute to a steadily increasing role for electrical power. In the Republic of Korea, where nuclear power already is a major producer, *per capita* electricity consumption has grown from 70 kWh per year in 1960 to almost 3200 kWh per year in 1992.

Over the next decades, the projected growth in the Earth's population, mostly in developing countries, will place higher demands on energy and electricity supplies. According to the World Energy Council, global consumption of electricity can be expected to increase between 50% to 75% by the year 2020. The potential clearly exists for nuclear power to play an important role as a safe and clean source of electricity to help countries meet their future energy needs. ❐