The future role of nuclear power in the global energy balance

Growth will be modest, but nuclear energy's contribution will remain significant into the next century

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Predictions of energy demand and supply beyond the year 2000 should be viewed with great caution. They involve taking into consideration many variables that are difficult to assess. However, general trends can be identified more or less reliably.

A sound judgement on the role of nuclear power in the global energy balance within the time span of the next 30 years should logically be based on the consideration of at least a number of factors. These include global trends in energy and electricity demand; practically available or estimated sources of supply; major requirements that these energy sources should meet; nuclear power's own potential; a realistic assessment of nuclear power's present status; and problems related to nuclear power.

Global energy and electricity trends

Predictions made at the 1989 Congress of the World Energy Council (WEC) show that between 1985 and 2020 world energy consumption will rise by 50% to 75%. IAEA estimates issued in 1991 for a more limited time period, 1990-2010, show a projected increase in energy consumption of between 28% and 41%. IAEA estimates of total electricity generation over this time period show an annual growth rate of 3% to 4%. In some regions — Latin America, Africa, the Middle East and South Asia, Southeast Asia and the Pacific, and the Far East — electricity generating capacity is projected to almost double by the year 2010. *(See table.)*

Estimates of total electricity generating capacity (GWe)

	1990	2000	2010
North America	857	1 125	1 394
Latin America	167	288	412
Western Europe	584	707	837
Eastern Europe and USSR	482	664	827
Africa	76	131	194
Middle East and South Asia	161	249	362
South East Asia and Pacific	79	113	150
Far East	389	532	729
World total	2 795	3 809	4 904
OECD countries	1 655	2 110	2 558
CMEA countries	471	649	811
Rest of the world	669	1 051	1 535

Source IAEA Data are for the low-growth scenario

Thus, WEC and IAEA predictions correlate in forecasting a rapid growth in demand. Some other studies, including those made by the International Energy Agency of the Organization for Economic Co-operation and Development

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(IEA/OECD), Commission of the European Communities (CEC), and International Institute of Applied Systems Analysis (IIASA), agree with the major trend.

Available energy resources

When studying large-scale world energy growth problems over the next 30 years, consideration of the means able to solve them should naturally be limited to those sources and technologies that are already proven and economically competitive, or to those that are under development and might be expected to contribute economically within the projected time frame.

This condition practically limits consideration to some well known "conventional" energy sources, such as coal, oil, gas, hydropower, and nuclear energy.

Regarding alternative energy sources now in developmental stages, such as solar, wind, biomass, geothermal, and tidal power, they necessarily have to be excluded from the list of practically available, proven, and economically competitive large-scale energy sources. The WEC conclusions in 1989 stated that new and renewable sources of energy are estimated to meet no more than 3% of the world's energy demand in 2020.

To assess the potential role of conventional energy sources, including nuclear energy, several economical, political, environmental, and social factors that may govern decisions of energy policy makers should be considered. The most important of these are economic competitiveness, health and environmental impacts, long-term availability of resources, desirability of diversification of supplies, and public acceptance.

In light of these factors, a brief review of the available large-scale energy sources finds that:

Coal will be available for many centuries and will probably be economically competitive within existing environmental requirements. However, it is ecologically unsound in the long term. Introduction of new sophisticated purification technologies may significantly reduce nitrogen oxide and sulphur dioxide emissions while reducing coal's economic competitiveness at the same time. But the "greenhouse effect" would in any case remain the major negative factor. Carbon dioxide taxes may further reduce competitiveness.

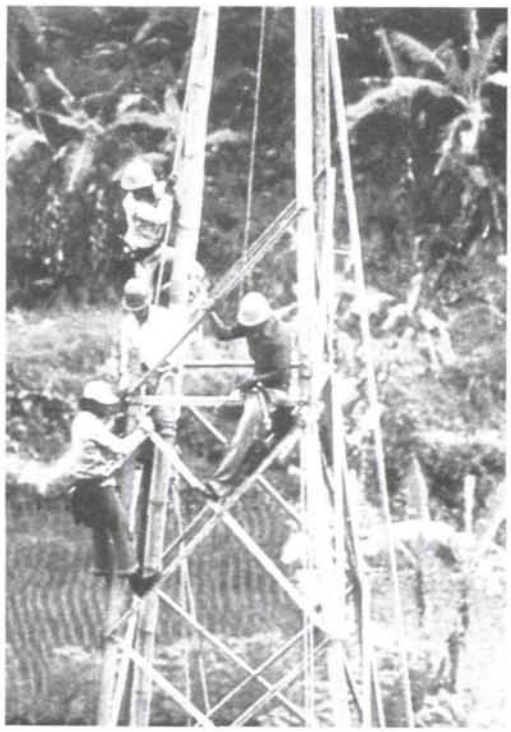
Oil and gas may be available for a number of decades with steadily increasing costs and, accordingly, decreasing economic competitiveness. However, they could and should be more efficiently used in chemical industries as feedstocks. Both are ecologically better than coal when burned. Natural gas, in terms of carbon dioxide output, is better than coal by a factor of two, but pipeline leakages of 1% to 2% may offset its advantages. Securing supplies from remote regions may cause serious problems from time to time.

Hydropower has a limited potential. About 60% of the world's hydropower potential is already exploited, and in industrialized countries exploitation is close to 100%. Hydropower is considered ecologically clean, but on closer scrutiny it is not so environmentally benign because of its impact on storage areas and water flow patterns, for example.

Nuclear energy resources will be available for centuries, particularly with utilization of plutonium, and is economically viable. Under normal operations, nuclear energy plants are ecologically clean and they can be made acceptably so under accident conditions. Nuclear energy is practically independent of normal fuel supply problems. Despite its proven and potential advantages, nuclear energy's future is still uncertain in many countries.

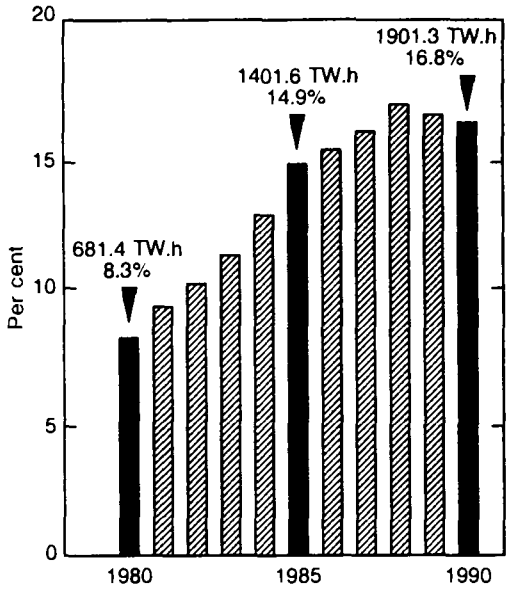
Present status of nuclear power

Today 24 countries benefit from nuclear-generated electricity. In addition, four other countries — China, Cuba, Islamic Republic of



In Southeast Asia and other regions of the developing world, electrical generating capacity is projected to double over the next two decades. Here, workers check electricity lines in Indonesia. (Credit: EdF)

Nuclear electricity generation and share of total electrical energy in the 1980s



Source IAEA

Iran, and Romania — have their first nuclear power plants under construction.

At the end of 1990, there were 423 nuclear reactors in operation around the world, with a total installed net nuclear capacity of 326 gigawatts-electric (GWe). There were also 83 nuclear reactors under construction totalling nearly 66 GWe. During 1990, ten new reactors were connected to electricity grids in Canada, France, Japan, United States, and the USSR.

In energy terms, nuclear power generated about 1901 terawatt-hours of electricity during 1990, an increase of 2.5% over 1989, and accounted for about 16.8% of the world's total electricity generation. *(See graph.)* In France, 75% of the electricity is generated by nuclear power; in Belgium, 60%; Hungary, 51%; Republic of Korea, 49%; and Sweden, 46%. Ten countries now generate more than 30% of their electricity from nuclear power.

Future outlook for nuclear power (in GWe)

	1990		2010 (low- and high-growth scenarios)			
	Nuclear capacity	Share of total electrical capacity	Projected nuclear capacity		Share of total electricity capacity	Average annual rate of addition
			Additions	Total		
World total	326	11 7%	130	456	9 3%	1.7%
			251	577	10.0%	2.9%
Developing countries	18	2 7%	28	46	3.0%	4 7%
			55	73	3.6%	7 2%

Source IAEA

In terms of installed nuclear capacity, States belonging to the OECD accounted for 81.4% of the installed capacity in 1990, with States which belonged to the Council for Mutual Economic Assistance (CMEA) accounting for 13%. Developing countries accounted for 5.6%.

Although the Chernobyl accident has drastically influenced nuclear power development and plans in a number of countries, particularly in the USSR, in the period since the accident some 98 GWe have been built worldwide, while about 24 GWe have been shut down or cancelled.

Future outlook for nuclear power

During the next 10 years, growth in nuclear power will not resemble the past. Not only have the growth rates for electricity consumption in industrialized countries declined over the past decade, due to either cancellations or delays in previously planned capacity additions, but public concerns regarding nuclear power have heightened. Thus, actual growth has consistently been lower than forecasted. Due to the continuing long period for implementation, nuclear generating capacity additions in the short term (up to about the turn of the century) will largely be determined by past decisions, although construction, licensing delays, or policy changes could still have an affect. The situation after the year 2000 is less predictable but perhaps less gloomy.

According to the IAEA's recent estimates, the total projected increase in nuclear generating capacity, in the low scenario, is from 326 GWe in 1990 to about 460 GWe in 2010. This corresponds to an average annual growth rate of 1.7% and a total increase of about 130 GWe during this period. *(See table.)*

During the same period, nuclear generating capacity in developing countries (i.e., States that are neither OECD nor CMEA members for statistical purposes) is expected to reach 46 GWe by the year 2010. This corresponds to 28 GWe of nuclear capacity additions and an average annual growth rate of 4.7%. Nuclear power in developing countries is expected to continue to gain an increasing share of electricity generation, from a 4% share in 1990 to 6% by 2010. In capacity terms 22% of all new nuclear generating capacity to be placed in commercial operation in the world by 2010 is expected to be in developing countries.

Factors influencing nuclear prospects

A number of factors influence nuclear power's prospects.

Economics. The economics of nuclear power, as well as of other energy sources, is a moving target rather than a granted advantage. A recent joint assessment by the IAEA and the Nuclear Energy Agency of the OECD shows that nuclear power is still highly competitive in a number of countries. However, its competitiveness is closely dependent upon such well-known factors as licensing and construction times, degree of standardization, interest rates, and costs of competitive fuels. Therefore, to maintain and further improve the economic competitiveness of nuclear power, further steps should be undertaken, particularly in such institutional areas as licensing.

Some developments, particularly in the field of advanced reactors, are based on proven technologies and provide a good basis from which to get easily licensed, simpler, safer, and cheaper reactors. The natural trend of gradually rising oil and gas costs, given depletion of resources, will also work to benefit nuclear energy.

Environmental impact. One cannot separate the economics of energy and its environmental consequences. Environmentally friendly, competitive, and commercially viable energy sources may be an oxymoron. A cost-benefit analysis of the various options available for use may well find that, of those costs and benefits that are quantifiable, the one energy source that will give the most for the least is nuclear power. The Intergovernmental Panel on Climate Change (IPCC), created by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), was formed in 1988 to provide a scientific assessment of and elucidate response strategies to global warming. Its final report, produced in 1990, has now served as the platform from which international negotiations have commenced to prepare a framework convention on global warming. For the energy sector, "low and non-CO_2 emitting" energy sources are the preferred means. Nuclear power is not explicitly mentioned, although in background documents it does appear. Since its inception, the IAEA has been involved in the IPCC, especially in the area of response strategies, to present factual information on nuclear power and to place it in perspective with other energy sources.

Nuclear power is seen as one of the most feasible sources now available to generate electricity in the quantities needed and without producing greenhouse gases. It is already helping to avoid additional carbon dioxide emissions. If the electricity currently produced by nuclear had been produced by coal instead, it would have resulted in approximately 2 billion tons annually of additional carbon dioxide emissions. In an analysis prepared for the IPCC, the IAEA assumed two post-2000 growth paths for nuclear power of 40 and 60 GWe per year, respectively. The analysis was not a forecast, but rather a hypothesis: Given political will, what would be the amount of carbon dioxide avoided should one pursue one or the other path?

The implications of the analysis are that by the year 2010, the assumed addition of nuclear power could avoid some 30% to 38% of the carbon dioxide emissions compared with the case if coal were used instead. *(See table.)*

Safety and radioactive waste. The Three Mile Island accident, and especially the one at Chernobyl, have sharply increased the attention of people and governments on the safety of nuclear power operations.

The IAEA has long served as an instrument for building an international consensus on safety standards and practices. These standards have been updated to reflect current thinking, experience gained, and major technological advances. While standards and regulations are indispensable to ensuring nuclear safety, equal attention must be paid to operational safety practices. The IAEA assists its Member States by offering a range of services in this area, both with respect to operating nuclear plants and to those being built.

With respect to radioactive waste management, both national and international efforts should be strengthened to fill the communications gap regarding the actual technological status of disposal systems and the public's awareness of them. The major steps should include experimental confirmation of the reliability of different waste disposal aspects, particularly those supporting the validity of scientific predictions over the long term. Actual operation of a prototype waste disposal repository would be very important.

Potential carbon-dioxide emissions avoided by a nuclear development path (in million tonnes of carbon)

	1988	2000	2010
*Business-as-usual scenario**			
CO_2 avoided	438	660	870
Percentage reduction**	21%	21%	21%
Case 1 (+40 GW/yr) ***			
CO_2 avoided	438	660	1270
Percentage reduction**	21%	21%	30%
Case 2 *(+60 GW/yr)* ***			
CO_2 avoided	438	660	1590
Percentage reduction**	21%	21%	38%

* Nuclear power is introduced at a rate keeping its percentage in the energy mix constant at 1988 level.

** Relative to total emissions that would result if nuclear were replaced by coal.

*** After the year 2000.

The IAEA has recently initiated a programme covering safety standards and guides for safe long-term storage of spent fuel, as well as for management and disposal of high-level radioactive wastes.

Decisions and public involvement

The availability of energy is essential for the world economy. The demand for energy has been increasing at an annual rate of 3% since 1986, in comparison with the stagnated annual growth rate of around 1% after the second oil crisis in 1979. Current predictions show that, despite conservation measures, world energy demand will rise over the next 30 years by 50% to 75%.

Electricity is a preferred end-use form of energy for both developing and industrialized countries. Its use is convenient, efficient, and versatile. Increasing demands for electricity are the logical future development.

In years ahead, nuclear power will retain, and may even enhance, its position as an important element in the world's energy supply mix, given rising electricity demand and concerns over environmental protection. Future developments will depend, to a considerable extent, on the nuclear community's efforts in reducing public concerns and restoring confidence in the nuclear option. Energy decisions, while never the sole domain of governments, are coming under increasing public scrutiny and people wish to be involved in deciding key directions of energy policy.

For its part, the IAEA will continue to play an instrumental role in assisting countries to plan optimal energy and electricity systems, taking into due consideration issues of global energy security and environmental protection.

Oil, gas, coal, hydropower, and nuclear energy are expected to remain the world's main fuels for electricity generation well into the next century. (Credit: *Ascent*, AECL)