Perspectives on the Future of Nuclear Fission Energy

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The main concern of national authorities responsible for energy policy is attaining a reliable supply of electricity with a competitive cost and acceptable environmental impact. Indeed, this objective represents a big challenge.

Energy demand in industrialized countries continues to rise, while nowadays a large part of the world's population still lacks electricity supply or any other advanced technology providing energy supply, posing a major hindrance to their development. Moreover, the energy consumption of densely populated countries, like China or India, is growing remarkably fast, making a significant contribution to the increase of global energy demand.

The main sources of primary energy continue to be fossil fuels, which entails the exhaustion of existing reserves and, as a result, supply tensions and a rise in energy prices, as well as the increase of CO_2 and other greenhouse gas emissions.

Meanwhile, the broad consensus of the scientific community on the connection between the continuous growth of these emissions and global warming and its risks is causing ever greater public concern.

Bearing in mind all these considerations, future expansion of nuclear energy will depend, to a large extent, on the ability of nuclear energy to contribute to alleviating the above-mentioned concerns and to reaching a sustainable energy model.

Nuclear energy development and present status

Construction of nuclear power plants grew at astonishing pace in the aftermath of the first petrol crisis, peaking in the early 1980s. However, this expansion dramatically slowed down after the Three Mile Island accident (1979), and even more after the Chernobyl accident (1986). During the

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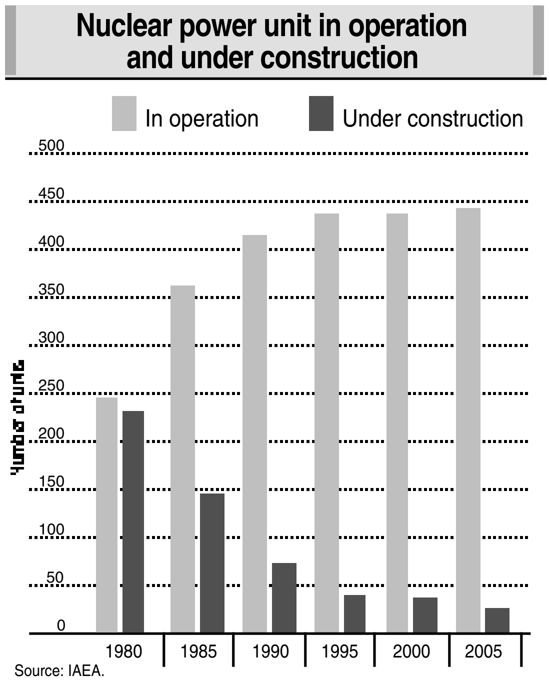


1990s, the number of units that entered into operation was 19, and only 6 more new plants were connected to the grid between 2000 and 2005.

Nevertheless, rate power increases, as well as specific improvements in nuclear power plant operations, have led to an important increase in nuclear generation over the last 20 years. In the 1990s the world average annual capacity factor of the nuclear fleet was 67.7 per cent, while in 2005 this reached 81.4 per cent. This difference is equivalent to 75 new 1000 MW power plants. As a result, nuclear energy's share of total world electricity generation has risen from 7.8 per cent in 1980 to 15.5 per cent in 2005.

By the end of 2007, there were 439 nuclear reactors in operation worldwide, almost half located in three countries: USA (104), France (59) and Japan (55). Of the 30 countries with nuclear power plants in operation, 9 generate more than 40 per cent of their total electricity production from nuclear power, while 7 additional countries have a nuclear share in their electricity generation of around 30 per cent.

Factors influencing the future expansion of nuclear energy

Future expansion of nuclear power is dependent upon a number of factors, some of them applicable to all electricity generation technologies and others specific to nuclear power. Within the former there are factors connected to generation costs, security of supply and environmental impact.

Nuclear power plants have high construction costs, while costs of operation are relatively low. This makes it very profitable to extend, as much as feasible, the life of the nuclear power plants in operation. Besides, the relatively low influence of nuclear fuel prices favours the medium and short term stability of electricity generating costs. In fact, uranium prices represent only 5 per cent of the total generation cost of nuclear energy, making nuclear electricity costs much less sensitive to changes in fuel prices than fossil-fired electricity generation.

NUCLEAR POWER UNITS IN OPERATION BY REGION

	1980	1985	1990	1995	2000	2005
North America	79	106	128	130	117	121
Latin America	1	3	4	5	6	6
Western Europe	103	147	153	149	148	135
Eastern Europe	31	54	65	68	69	70
Africa		2	2	2	2	2
Middle East and South Asia	5	7	8	11	16	17
South East Asia and Pacific	-	-	-	-	-	-
Far East	26	44	56	70	77	90
Total	**245**	**363**	**416**	**435**	**435**	**441**

Source: IAEA.

However, for new plant construction, the economic competitiveness of nuclear power depends on the country and other circumstances. From several reports in which the comparative costs of different energy sources (including coal, natural gas and nuclear) are studied, it can be concluded that none of these sources can be considered the least expensive in all circumstances, since this will depend on the specific conditions of each project, hypotheses about financial costs, fuel prices changes, etc.

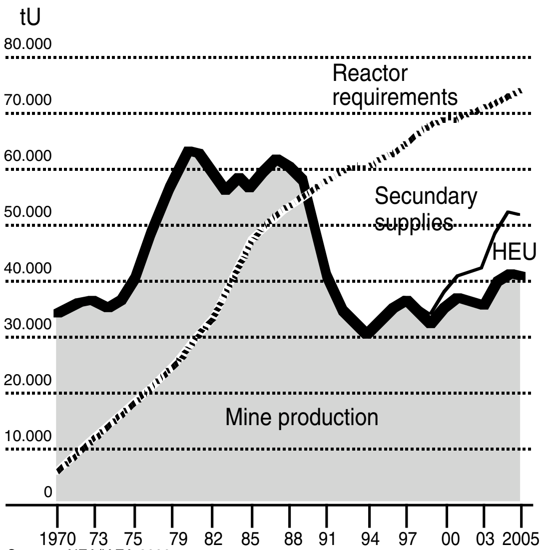
It also depends on the future price of CO_2 emissions. A charge on carbon dioxide emissions benefits nuclear energy, yet at the same time this energy has to bear the expenses connected to dismantling installations as well as radioactive waste management. Final disposal of spent fuel and high level radioactive waste costs generate uncertainties, since the result of on-going technological developments may condition the final decision about the strategy to adopt, and, consequently, its price.

In any case, as high construction costs are the prime factor to count against nuclear projects, plant designers are putting all their effort into standardizing new nuclear power plant designs, requiring lower investment and shorter licensing procedures and construction times.

As regards security of supply, nuclear energy contributes to the diversification of available energy sources. Substantial uranium resources are still available, and comes mainly from politically stable countries. According to estimates from the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), with current technology and the generation rate of nuclear power, identified uranium reserves will be enough to satisfy the fuel demand of the world's nuclear reactor fleet for up to 85 years, and this time span could be much longer thanks to new technological developments.

Approximately 96 per cent of the world's uranium production comes from ten countries, two of which (Australia and Canada) supply about 50 per cent of world production. Since the early 1990s there has been a remarkable imbalance between uranium supply and demand. Last year's

Global annual uranium production and reactor requirements

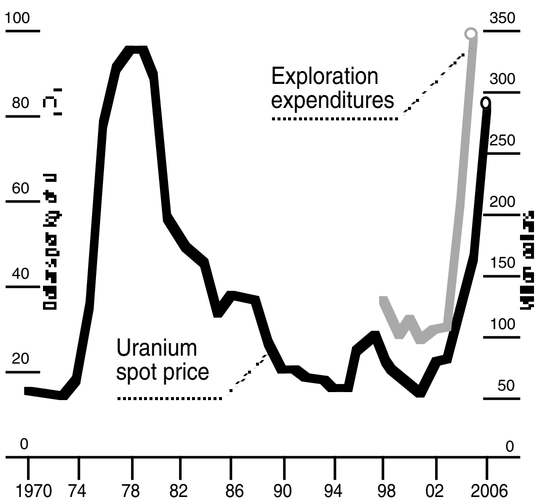


Sources: NEA/IAEA 2006.

mine production represented only 50-60 per cent of world demand, with the remaining demand being met from secondary sources, including large existing stocks of natural and enriched uranium, uranium from reprocessing, use of MOX (mixed oxide fuel, with U235 partially substituted by Pu239 coming from fuel reprocessing), re-enrichment of depleted uranium tails (with U235 concentration lower than 0.7 per cent, which is the enrichment of natural uranium) and downblending highly enriched uranium (HEU) coming from military stockpiles.

Since 2003, uranium prices have suffered a remarkable rise, but, as mentioned before, this cost represents only a small contribution to total nuclear generation cost. This increase is mainly due to future nuclear plant construction expectations, secondary source exhaustion and US dollar weakness (the currency commonly used in financial transactions). However, as a result of uranium price increases, uranium prospects and production activities have increased considerably over recent years, and it is expected that they will continue to increase over coming years, which could lead to uranium price stabilization.

Development of uranium prices



Sources: NEA/IAEA 2006.

In relation to environmental impact, current estimates of greenhouse gas (GHG) global emissions indicate they will increase worldwide in the coming years. The latest assessment report from the Intergovernmental Panel on Climate Change (IPCC), published last November, states that climate change effects have already been observed, and that short-term measures should be applied in order to reduce these emissions.

Nuclear energy, with very low GHG emissions taking into account the whole nuclear fuel cycle, is a technology that can contribute to this reduction, and enable countries to meet their Kyoto Protocol commitments. In the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), and in the Meeting of the Parties to the Kyoto Protocol, which took place in Bali last December, nuclear energy was not one of the main subjects of discussion.

Furthermore, as mentioned above, nuclear energy is also influenced by several specific factors that should also be taken into account, and whose future development will determine the energy source's role over the next few years. These specific factors are: safety operations of nuclear power plants, final disposal of radioactive waste, and nuclear proliferation risk.

The safety of nuclear power plants has undergone progressive improvements, mainly during the 1990s, as a result of an increase in regulatory awareness and requirements, improvements in plant operations and deployment of technological advances. It can therefore be concluded that a high level of safety has been reached. In the future, this level is expected to continue rising because of the introduction of new generation reactors and passive safety features that will minimize the risk of severe accidents.

However, possibly the greatest challenge that nuclear energy has to face in the coming years is final disposal of spent fuel and high level waste, since after more than fifty years of nuclear generation proven solutions are not yet available.

Two different management strategies are being implemented for spent nuclear fuel. The first lies in reprocessing the spent fuel to recover usable materials (uranium and plutonium) for manufacturing mixed oxide fuel (MOX). Approximately one third of the world's spent fuel has been reprocessed so far, although due to limited MOX fuel manufacturing at the present time less than 50 per cent of the world's reprocessing capacity is used. The second strategy lies in managing spent fuel as radioactive waste without further use, housing it in temporary storage facilities until final disposal in a deep geological repository.

The Finnish, Swedish, French and US repository programmes continue to be the most advanced, but none of these countries is likely to have available a repository in operation before 2020. On the other hand, the development of actinides transmutation and separation technologies could assist volume reduction of the radioactive waste to be managed, as well as reduction of its radiotoxicity.

Most countries store the spent fuel, keeping abreast of technology developments in both fields, in order to take future decisions on the strategy to put in place. Meanwhile, there are temporary storage technologies available, both dry and wet, which are widely proven and enable storage needs to be met.

Finally, the discovery of undeclared nuclear-weapons programmes over recent years has increased concerns over nuclear proliferation. Furthermore, prevention of nuclear proliferation could be more difficult to pursue in a world with a larger nuclear energy sector, with more nuclear material and more countries and facilities to be controlled, unless reinforcement of non-proliferation methods is also implemented.

Spreading sensitive technologies, such as uranium enrichment and reprocessing of spent fuel, among countries interested in peaceful uses of nuclear energy could also contribute to the risk of proliferation. To address this risk, some countries and the IAEA have recently proposed a number of different options aimed at setting up multilateral arrangements for providing fuel enrichment and reprocessing services in facilities subject to direct IAEA supervision and control. Against the same background, a new initiative, called the Global Nuclear Energy Partnership (GNEP), supported so far by 21 countries, has the objective of developing advanced nuclear fuel cycle technologies to foster nuclear energy expansion, reduce generation of radioactive waste and minimize proliferation risks.

Future nuclear power development outlook

In recent years, there have been signals of increasing expectations over the possible revamping of nuclear power development. Many factors have contributed to these expectations, including continued improvements in the performance of nuclear power plants, security of supply concerns in a framework of persistently growing energy demand, and the need for additional energy supply at affordable and stable prices against a background of present and future environmental constraints.

Some countries such as China, India, Japan, the Republic of Korea and the Russian Federation have announced nuclear power expansion plans, and an increasing number of developing countries are considering the use of nuclear power to meet their energy needs and to sustain their economic growth.

Several international organizations periodically publish updated projections of nuclear power expansion throughout the different regions of the world in the long and medium terms, as well as of the share of nuclear energy in the world's electricity generation.

These projections take into account the number of reactors under construction or firmly planned as of today, expected shutdown or life extension programmes and long term nuclear power expansion plans announced by

NUCLEAR POWER CAPACITY IN THE LOW AND HIGH ESTIMATES: 2006 PROJECTIONS (GWe)

	2005	2010		2020		2030	
		Low	High	Low	High	Low	High
North America	111	114	116	120	131	126	158
Latin America	4	4	4	6	7	6	18
Western Europe	124	122	124	91	129	48	149
Eastern Europe	48	48	50	68	76	78	107
Africa	2	2	2	2	4	2	10
Middle East and South Asia	3	10	11	17	27	23	46
South East Asia and Pacific					1	1	5
Far East	76	81	83	119	145	130	187
World Total	**368**	**381**	**390**	**423**	**520**	**414**	**679**

Source: IAEA.

ESTIMATES OF TOTAL ELECTRICITY GENERATION AND THE SHARE OF NUCLEAR POWER (2005-30)

	2005		2010 (a)		2020 (a)		2030 (a)	
	Total electricity TW-h	Nuclear share (%)	Total electricity TW-h	Nuclear share (%)	Total electricity TW-h	Nuclear share (%)	Total electricity TW-h	Nuclear share (%)
North America	4631	18.8	4.743	19	5.414	18	6.057	17
			4993	18	6.111	17	7.430	17
Latin America	1.116	2.3	1.187	3	1.613	3	2.206	2
			1.326	2	2.103	3	3.442	4
Western Europe	2.995	29.4	3.177	28	3.464	20	3.756	10
			3.325	27	4.280	23	5.535	21
Eastern Europe	1.723	18.2	1.797	17	2.076	22	2.358	23
			1.917	17	2.629	19	3.789	20
Africa	510	2.4	570	3	740	2	931	2
			607	2	961	3	1.509	6
Middle East and South Asia	1.240	1.5	1.346	4	1.789	6	2.313	6
			1.519	4	2.407	7	3.672	8
South East Asia and Pacific	530		717		915		1.138	1
			746		1.064	1	1.510	2
Far East	4.087	12.4	4.280	13	5.231	16	6.328	15
			4.958	12	7.578	13	11.303	12
World Total								
Low Estimate	**16.930**	**15.5**	**17.818**	**16**	**21.242**	**15**	**25.087**	**12**
High Estimate			**19.391**	**15**	**27.133**	**14**	**38.191**	**13**

Source: IAEA.

governments. High and low projections are based on the opinion of energy experts about the feasibility of implementing this expansion. The first table in this page shows the low and high estimates for nuclear capacity expansion for different regions made by the IAEA in 2006.

According to these projections, the low estimate of world nuclear power capacity increase in the period 2005 to 2030 is about 13 per cent, while it could reach 85 per cent according to the high estimate.

However, the study shows major differences according to the region in question. For example, in Western Europe the high estimate predicts an expansion of nuclear power capacity of only 20 per cent over the next 25 years, while the low estimate projection for this region foresees a reduction of nuclear energy capacity as a result of the shutdown of older nuclear power units without new builds. In contrast, the Far East low and high estimate projections predict a continuous growth of nuclear energy, even rising above the projected capacity in North America by 2030.

The second table of the previous page, shows IAEA estimates of total electricity generation and the share of nuclear power generation in the eight regions of the world for every ten years up to 2030.

As shown in the table, the maximum total share of nuclear power will decline from 15.5 per cent in 2005 to 13 per cent in 2030, as the expansion in total electricity generation capacity will be higher than the increase in nuclear power. While this share in Western Europe is projected to decline in both the high and low estimates, in Middle East and South Asia the prediction is that there will be a continuous increase.

The International Energy Agency estimations for 2030, published in its World Energy Outlook, are very similar to the projections of IAEA in terms of the lower estimates, although they are lower when the high estimates are compared. There are some other similar studies carried out by other organisations, whose conclusions depend on hypotheses about energy programmes in the different countries and their future energy needs.

To sum up, the interest in nuclear power and its future expansion will depend on global economic factors such as: fossil fuel price trends and the ability of next generation nuclear technology to cut capital costs; governmental policies to limit carbon emissions from growing energy use, reduction of energy imports and reinforcement of security of supply. But other nuclear specific factors must be taken into account, such as: development of technologies for radioactive waste disposal; effectiveness of the measures being implemented to handle nuclear proliferation concerns; and, above all, continued safe performance of the current nuclear fleet of reactors throughout the world and the development of public perceptions of this energy option.