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It's Present Status and Development Trends

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Present Status

According to data in the IAEA's Power Reactor Information System (PRIS), at the end of 1993 there were 430 nuclear power reactors connected to electricity supply networks (Table 1 and Figure 1), with a total installed nuclear power generating capacity of 337,820 MW(e). There were also 55 power reactors under construction (Table 1 and Figure 2), with a total generating capacity of 44,369 MW(e). Accumulated nuclear reactor operating experience reached approximately 8,900 reactor years. Worldwide in 1993, 32 countries were operating or building a total of 485 nuclear power plants for electricity generation.

As shown in Table 2, during 1993 nine new reactors having a total net capacity of 8,988 MW(e) were connected to the grid in 6 countries: Canada (1), China (1), France (1), Japan (4), Russia (1) and the USA (1), increasing the world's total installed nuclear power generating capacity by about 2%.

Construction work started during 1993 on six nuclear power reactors: Japan (1), Republic of Korea (2), Pakistan (1) and Russia (2), representing an additional net capacity of 4,415 MW(e). The Republic of Korea also reported in 1993 that two reactors had started construction in 1992. There were no nuclear plant shutdowns during 1993; however, information received by the IAEA in 1993 reported that one reactor had been shutdown in the USA in 1992 and two had been shutdown in the United Kingdom in 1991, which had not been reflected in the IAEA's data. Also, during 1993 construction was suspended or cancelled on 16 reactors in Russia. (See Table 3).

Nuclear power is a proven technology which already makes a large contribution to electricity supply, amounting to about 17% of the total electricity generation in the world, and to a much lesser extent to heat supply in some countries. Moreover, nuclear power is economically competitive with fossil fuels for base load generation in many countries, and is one of the commercially proven options that already is making a substantially contribution, which could be enlarged in the future, to reduce environmental burdens, especially green house gas emissions, from the electricity sector.

Figure 3 shows the growth of nuclear electricity generation since 1970. Nuclear electricity generation expanded rapidly in the 1970s and by 1980 had reached 694.3 TW•h, almost a nine-fold increase since 1970, and contributed 8.3% of the total electricity, representing an average annual growth rate of 24% in the decade 1970-1980. In the period 1980-1985 nuclear electricity generation increased from 681.4 to 1448.5 TW•h, corresponding to an average annual growth rate of 16.3%. During 1985-1990, generation increased from 1448.5 to 1901.2 TW•h which corresponds to an average annual growth rate of 5.6%. In the period 1990-1993, the nuclear electricity generation increased at an annual growth rate of only about 1%, growing from 1901.2 to 2096 TW•h. At present, nuclear power accounts for about 17% of the total electricity produced in the world.

There were no fundamental changes in the worldwide development of nuclear power during 1993. Most Member States with nuclear programmes followed established plans to build up the nuclear contribution to electricity production. The growth of the nuclear power in Eastern and South Asia continued increasing. Japan has brought four units into operation: Genkai 3, Hamaoka 4, Kashiwazaki Kariwa 4 and Shika 1, and has 6 units under construction, which are planned to be connected to the electricity grids in 1994 and 1996-1997. China has brought two reactors into operation in the last two years and plans to connect the third plant, Guangdong 2, during 1994. India's programme continues with 5

units under construction. Pakistan started the construction of a new plant in 1993 and the Republic of Korea's nuclear programme continues with seven units under construction: four PWR and three PHWR plants.

Table 4 shows the distribution of nuclear electricity generation during 1993. The five largest producers were the USA (610.3 TW•h), France (350.2 TW•h), Germany (145 TW•h) Japan (246.3 TW•h), and Russia (119.2 TW•h).

Figure 4 shows the nuclear share of electricity generation by country. Worldwide, seventeen countries (including Taiwan, China) relied upon nuclear power plants to supply at least 25% of their total electricity needs. Lithuania has the largest share of nuclear electricity, with about 87% of its total production, followed by France with about 78% and Belgium with 59%. The Eastern European countries show a high dependence on nuclear power generation; with the exception of the Russian Federation, which produces 12.5% of its electricity from nuclear power plants, the countries in this region have a nuclear share of electricity generation higher than 20%. The highest shares are: the Slovak Republic with 54% of its electricity generated by nuclear, Hungary with 43%, Slovenia 43%, Bulgaria 37%, Ukraine 33%, and the Czech Republic 29%.

Development Trends

Energy and electricity are essential for economic development and enhancement of the quality of life. Energy provides services, such as heating, cooling, lighting and motive power, to which the world's population aspire. During the last 30 years, the growth rate of energy demand in the world averaged 3.6% per annum, and the electricity consumption has grown consistently faster than the total primary energy demand, at a rate of 4.5% per annum. Future energy demand will depend on a number of factors but population growth and economic development will continue to be main driving forces, although changes in lifestyles and technological progress are likely to lead to less energy intensive societies.

By 2025, about 84% of the world's population will be in the developing countries (Figure 5), where the average electricity consumption per capita (Figure 6) is at present less than one tenth of the level in industrialised countries of OECD. The developing countries will account for 95% of the world's population growth between 1990 and 2025. Such a rapid population expansion in the developing countries, combined with urbanisation and the need to foster economic and industrial development, will call for drastic increase in energy and electricity supply. Technical breakthroughs and innovations are expected to improve the efficiency of production processes. Demand management policies as well as more efficient end use appliances will reduce the supply requirements for delivering the same quality of service. However, productivity gains are not infinite and structural changes will have little impact on the global demand worldwide.

A range of electricity generation technologies, based on fossil fuel burning, renewable energy sources and nuclear power, are available or under development. Factors that will influence strategies for electricity system expansion include economics, security of supply and health and environmental impacts. The increasing awareness of potential health and environmental impacts of human activities has already induced the development of cleaner and more efficient technologies. The implementation of abatement devices and the increase of efficiency of power plants have substantially reduced the emissions and other residuals from fossil fuel chains. Nevertheless, sustainability, and in particular significant reductions of greenhouse gas emissions, can only be achieved by a broader deployment of non-fossil energy sources for electricity generation. Most renewable energy sources other than hydropower still require considerable research and development effort before they will be ready for large scale deployment and economically competitive for base load electricity generation. Therefore, nuclear power is considered by many experts as being the most likely non-fossil energy source, which can be deployed on a significantly larger scale, for implementing electricity supply strategies aiming towards sustainability and competitiveness.

Nuclear power programmes have slowed down in many countries over the last years, due to lower than expected growth rates of electricity consumption in industrialised countries and also due to public concerns regarding nuclear safety and radioactive waste

disposal. However, in some countries nuclear programmes continue to be pursued strongly. In the short term, the prospects for nuclear power development are fairly clear, since the units to be commissioned by the turn of the century are already under construction. As described in the preceding section, at the end of 1993 there were 55 nuclear power plants under construction in 18 countries with a total capacity of some 44 GW(e). Taking into account some uncertainties related to construction and licensing lead times, the world wide growth of nuclear capacity may range from 8 to 15% between 1993 and 2000, reaching some 365 to 385 GW(e) of installed nuclear capacity in the world in 2000. Most of the additional nuclear capacity will be brought into operation in Asia and in Eastern and Central Europe. In Western Europe and North America, the need for additional nuclear power plants, as well as for any base load electricity generation capacity, is limited since electricity demand is not growing significantly. In the other regions of the world, nuclear power will remain a relatively small contributor to electricity supply.

A broad range of factors will influence nuclear prospects in the medium and long term. Technologies for reactors and fuel cycle facilities, as well as fuel resources, are available to sustain a large scale deployment of nuclear power worldwide. The barriers to nuclear power development are more institutional and organisational than technological. The main prerequisites to a revival of nuclear power are the alleviation of public concerns regarding safety and waste management, and the establishment of adequate mechanisms for technology adaptation and transfer as well as financing, that will facilitate the implementation of nuclear power programmes in developing countries where the need for electricity is the most important. The nuclear power plants of the present generation ensure already a high level of safety based upon built-in redundancy and relying on decades of experience with proven technology and engineering. Advanced reactors are being designed and developed with new approaches to address the challenge of increasingly demanding safety requirements by, inter-alia, utilising more passive safety systems in order to reduce the probabilistic risk of accidents and to achieve very low on-site and off-site impacts in the event of a potential accident. Furthermore, consensus on international practices and standards for nuclear safety is emerging. The ongoing discussions on the structure and content of a Nuclear Safety Convention should lead to the establishment of such a convention in the coming months. Technical options for final disposal of high level waste have been developed and tested at the laboratory level. Although they have not yet been fully implemented, they have been comprehensively assessed from the economic and safety view points. The implementation of high level waste repositories, which is planned for early in the next century by several countries, will demonstrate the ability to handle the issue with a satisfactory level of safety for both current and future generations. All these positive elements should enhance the public acceptance of nuclear power and facilitate its broader deployment.

The cost of electricity generation will remain a cornerstone for the assessment and choice of options in electricity system expansion strategies. Recent studies show that in many countries nuclear power is among the cheapest sources for base load electricity generation, especially where solid mineral fuels are not accessible at low production costs. Designers of advanced nuclear power plants are aiming towards reducing capital costs through streamlining the reactor systems and reducing the amount of material required for the construction. Investment costs will also be reduced by shortening construction lead times through using more components that could be prefabricated off-site. Depletion of non renewable natural resources and the enforcement of more stringent atmospheric pollution standards are likely to raise the cost of electricity generated by fossil fuel power plants, thereby making nuclear power even more attractive economically. Financing the high capital costs of nuclear power plants will remain a key issue in many developing countries which are contemplating the implementation of nuclear programmes. The implementation of new financing approaches with support from development banks would facilitate the development of nuclear power in these countries.

Forecasting nuclear power development in the medium and long term is a difficult exercise, taking into account the broad number of driving factors which cannot be assessed with any high degree of certainty. The scenarios developed by the IAEA are not meant to be a prediction of the likely evolution of nuclear power generation but rather are intended only to illustrate some plausible future possibilities. The medium term scenarios, up to 2015, are derived from a bottom-up approach based upon a review of nuclear power programmes and plans in Member States. The low and high cases (Table 5 and Figure 7) correspond to a set

of contrasting but not extreme assumptions on the parameters which will influence the realisation of these programmes.

The **low case** reflects the continuation of the present trend of stagnation in nuclear power development due to public opposition and low economic growth in OECD countries, institutional and socio-political uncertainties in Eastern and Central Europe, and lack of funding in developing countries. In that case, the nuclear units under construction will be completed but only those countries where nuclear programmes are already firmly committed will continue to order new units. In some countries, nuclear units will not be replaced at the end of their life time and the total installed nuclear capacity in these countries will decrease before 2015. The projected nuclear capacity in the world, in the low case, would be about 375 GW(e) in 2015, and the share of nuclear power in electricity generation worldwide would be only 12% at that date.

The **high case** reflects a moderate revival of nuclear power development that could occur in light of a more comprehensive assessment of the macro-economic and environmental aspects of the different options available for electricity generation. This revival will occur mainly in Western Europe and to a lesser extent in North America. In Eastern and Central Europe, nuclear power programmes will be implemented according to the present plans. In Asia, nuclear power will be developed in line with the rapid growth of electricity demand. In the high case, the total nuclear capacity is projected to reach 570 GW(e) in 2015, which will just allow the share of nuclear power in electricity generation to be maintained at its present level.

Table 1

Nuclear Power Reactors in Operation and Under Construction
(as of 31 December 1993)

	In Operation			Under Construction		
	No. of Units	Capacity (MW(e))	Share of World Capacity (%)	No. of Units	Capacity (MW(e))	Share of World Capacity (%)
Argentina	2	935	0.28	1	692	1.56
Belgium	7	5527	1.64			
Brazil	1	626	0.19	1	1245	2.81
Bulgaria	6	3538	1.05			
Canada	22	15755	4.66			
China	2	1194	0.35	1	906	2.04
Cuba				2	816	1.84
Czech Rep.	4	1648	0.49	2	1824	4.11
Finland	4	2310	0.68			
France	57	59033	17.47	4	5815	13.11
Germany	21	22657	6.71			
Hungary	4	1729	0.51			
India	9	1593	0.47	5	1010	2.28
Iran				2	2392	5.39
Japan	48	38029	11.26	6	5645	12.72
Kazakhstan	1	70	0.02			
Korea, Rep. of	9	7220	2.14	7	5770	13.00
Lithuania	2	2370	0.70			
Mexico	1	654	0.19	1	654	1.47
Netherlands	2	504	0.15			
Pakistan	1	125	0.04	1	300	0.68
Romania				5	3155	7.11
Russia	29	19843	5.87	4	3375	7.61
Slovak Rep.	4	1632	0.48	4	1552	3.50
Slovenia	1	632	0.19			
South Africa	2	1842	0.55			
Spain	9	7105	2.10			
Sweden	12	10002	2.96			
Switzerland	5	2985	0.88			
Taiwan (China)	6	4890	1.45			
Ukraine	15	12679	3.75	6	5700	12.85
UK	35	11909	3.53	1	1188	2.68
USA	109	98784	29.24	2	2330	5.25
Total	430	337,820	100	55	44,369	100

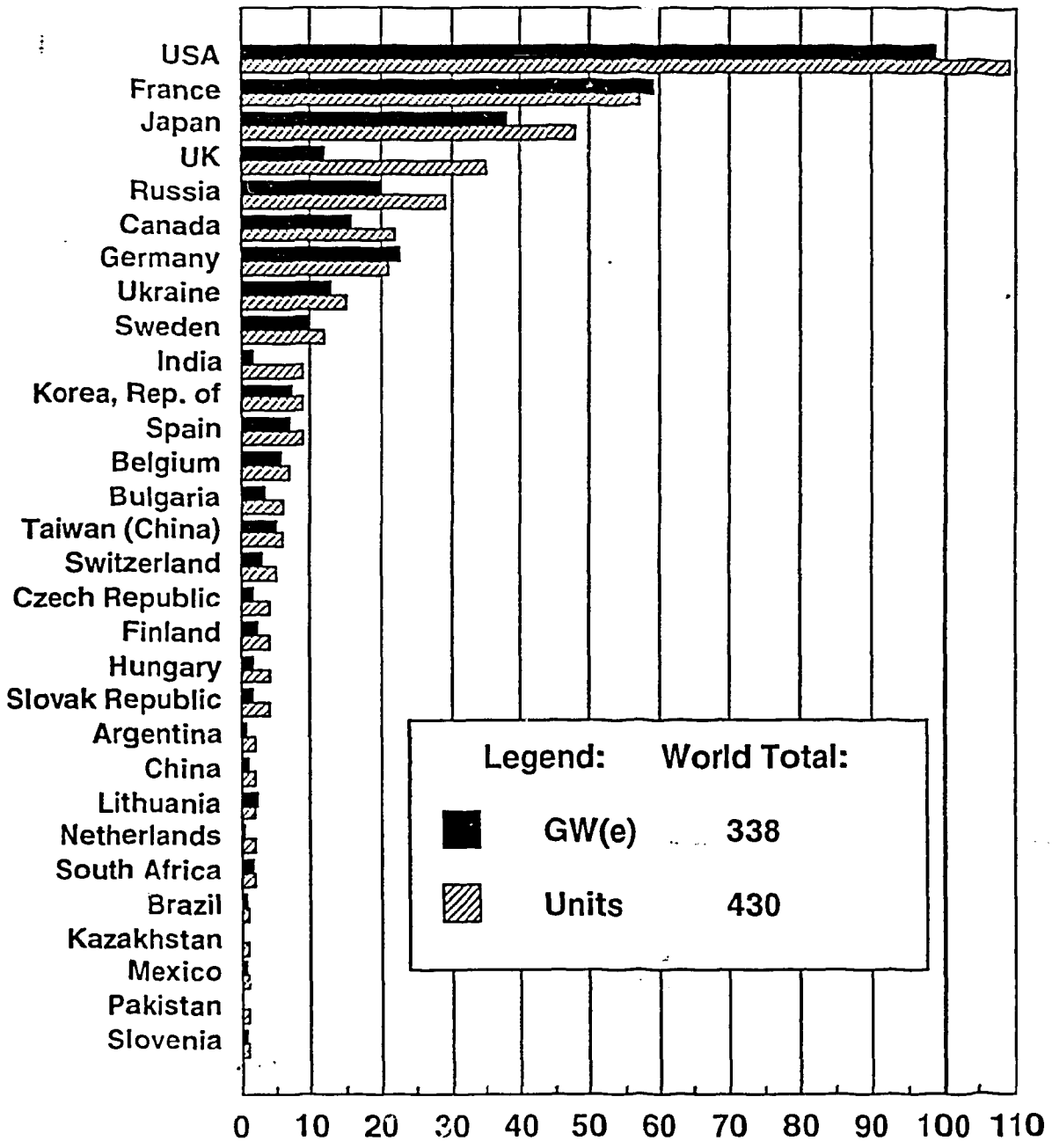

Figure 1. Nuclear Power Plants in Operation at End of 1993

Source: IAEA Power Reactors Information System (PRIS)

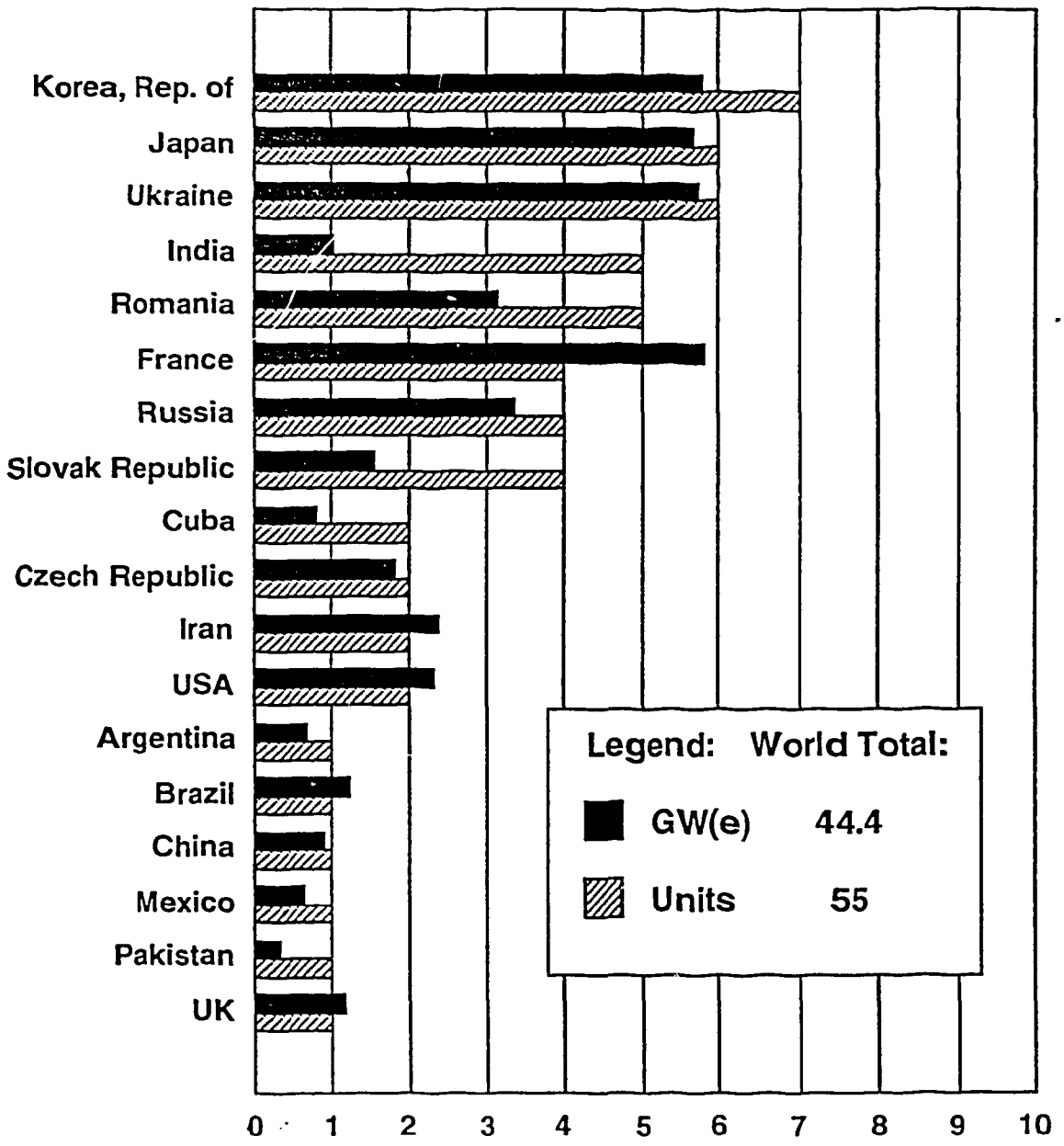

Figure 2. Nuclear Power Plants under Construction at End of 1993

Source: IAEA Power Reactors Information System (PRIS)

Table 2

Connections to Grid during 1993

Country	Reactor	Type	Net Capacity MW(e)	Date of Grid Connection
Canada	Darlington–4	PHWR	881	1993-4
China	Guangdong–1	PWR	906	1993-9
France	Golfech–2	PWR	1310	1993-6
Japan	Genkai–3	PWR	1127	1993-6
	Hamaoka–4	BWR	1092	1993-1
	Kashiwazaki Kariwa–4	BWR	1067	1993-12
	Shika–1	BWR	505	1993-1
Russia	Balakovo–4	PWR	950	1993-4
USA	Commanche Peak–2	PWR	1150	1993-4
TOTAL GRID CONNECTIONS		**9 Units**	8,988	

Table 3

Construction Starts and Suspensions or Cancellations in 1993

Country	Reactor Name	Type	Net Capacity MW(e))
Construction Started			
Japan	Kashiwazaki Kariwa–7	BWR	1315
Korea, Rep. of	Wolsong–3	PHWR	650
	Wolsong–4	PHWR	650
Pakistan	Chasnupp–1	PWR	300
Russia	South Urals–1	FBR	750
	South Urals–2	FBR	750
Construction Suspended			
Russia	Balakovo–5	PWR	950
	Balakovo–6	PWR	950
	Rostov–1	PWR	950
	Rostov–2	PWR	950
	Voronezh (Heat Only)–1	PWR	500*
	Voronezh (Heat Only)–2	PWR	500*
Construction Cancelled			
Russia	Bashkir–1	PWR	950
	Bashkir–2	PWR	950
	Bashkir–3	PWR	950
	Kalinin–4	PWR	950
	Kursk–6	LWGR	925
	Gorky (Heat Only)	PWR	500*
	Rostov–3	PWR	950
	Smolensk–4	LWGR	925
	Tatar–1 (Kama)	PWR	950
	Tatar–2 (Kama)	PWR	950

* Thermal output; no electricity production

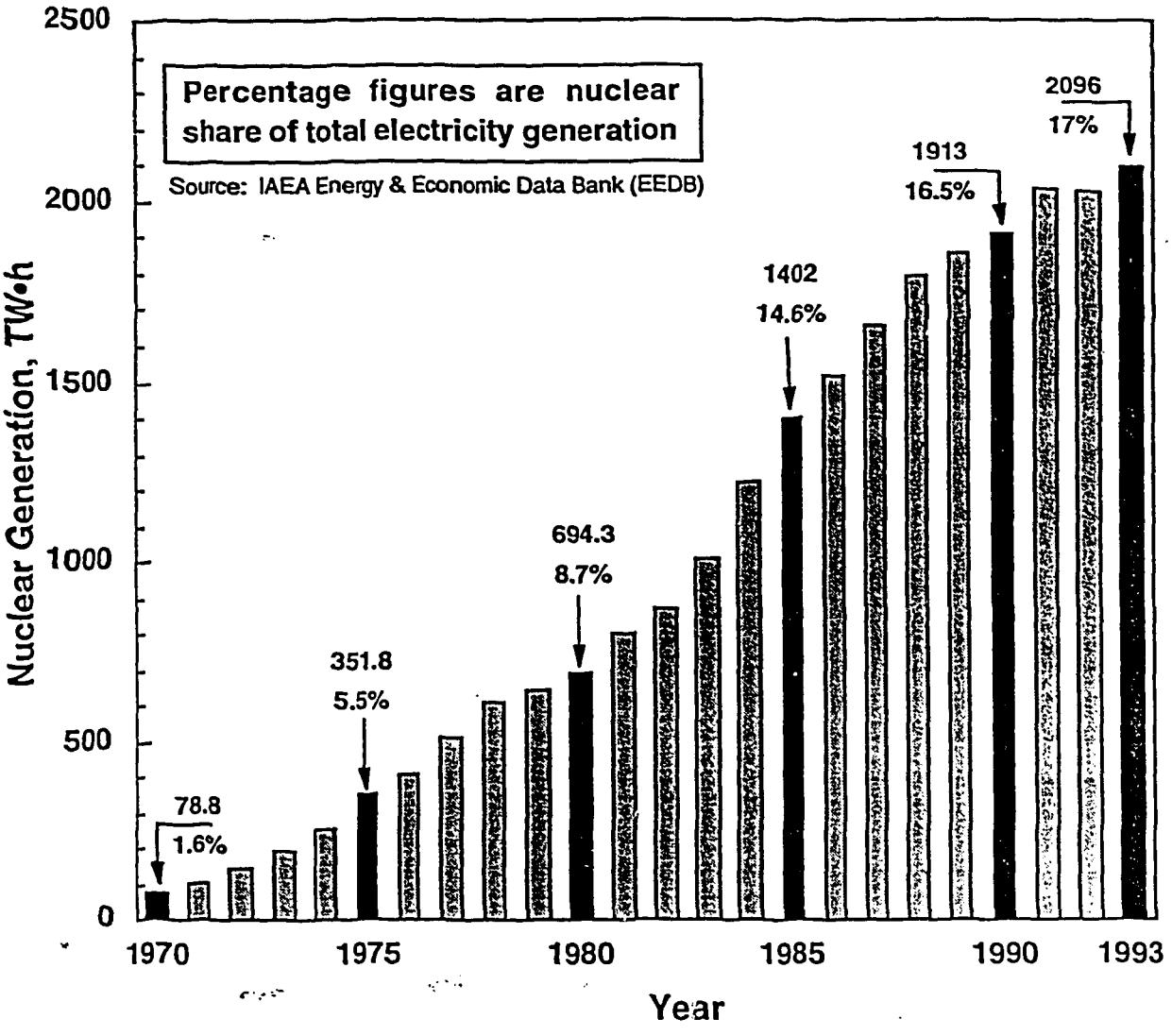

Figure 3. Growth of Nuclear Electricity Generation since 1970

Table 4

Distribution of Nuclear Electricity Generation in the World as of 31 December 1993

Country	Nuclear Generation TW • h	Country Share of World Nuclear Generation (%)
Argentina	7.2	0.34
Belgium	39.5	1.88
Brazil	0.4	0.02
Bulgaria	14.0	0.67
Canada	88.6	4.23
China	2.5	0.12
Czech Rep.	12.6	0.60
Finland	18.2	0.87
France	350.2	16.71
Germany	145.0	6.92
Hungary	13.0	0.62
India	5.4	0.26
Japan	246.3	11.75
Kazakhstan	3.6	0.17
Korea, Rep. of	55.4	2.64
Lithuania	12.3	0.59
Mexico	3.7	0.18
Netherlands	3.7	0.18
Pakistan	0.4	0.02
Russia	119.2	5.69
South Africa	7.2	0.34
Slovak Rep.	11.0	0.52
Slovenia	3.8	0.18
Spain	53.6	2.56
Sweden	58.9	2.81
Switzerland	22.0	1.05
Taiwan (China)	33.0	1.57
UK	79.8	3.81
Ukraine	75.2	3.59
USA	610.3	29.12
TOTAL	2096	100

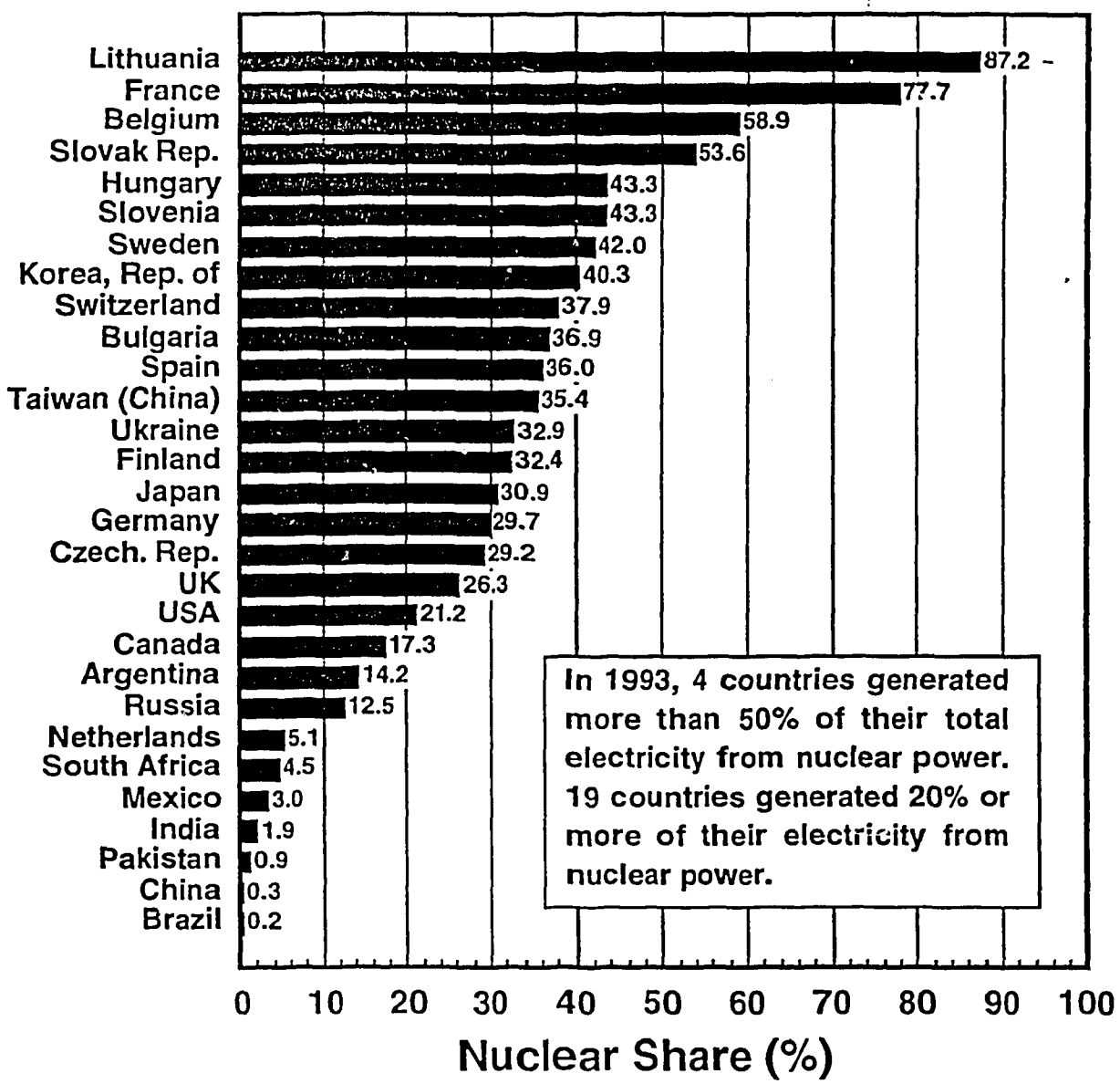

Figure 4. Nuclear Shares of Total Electricity Generation – 1993

Source: IAEA Power Reactors Information System (PRIS)

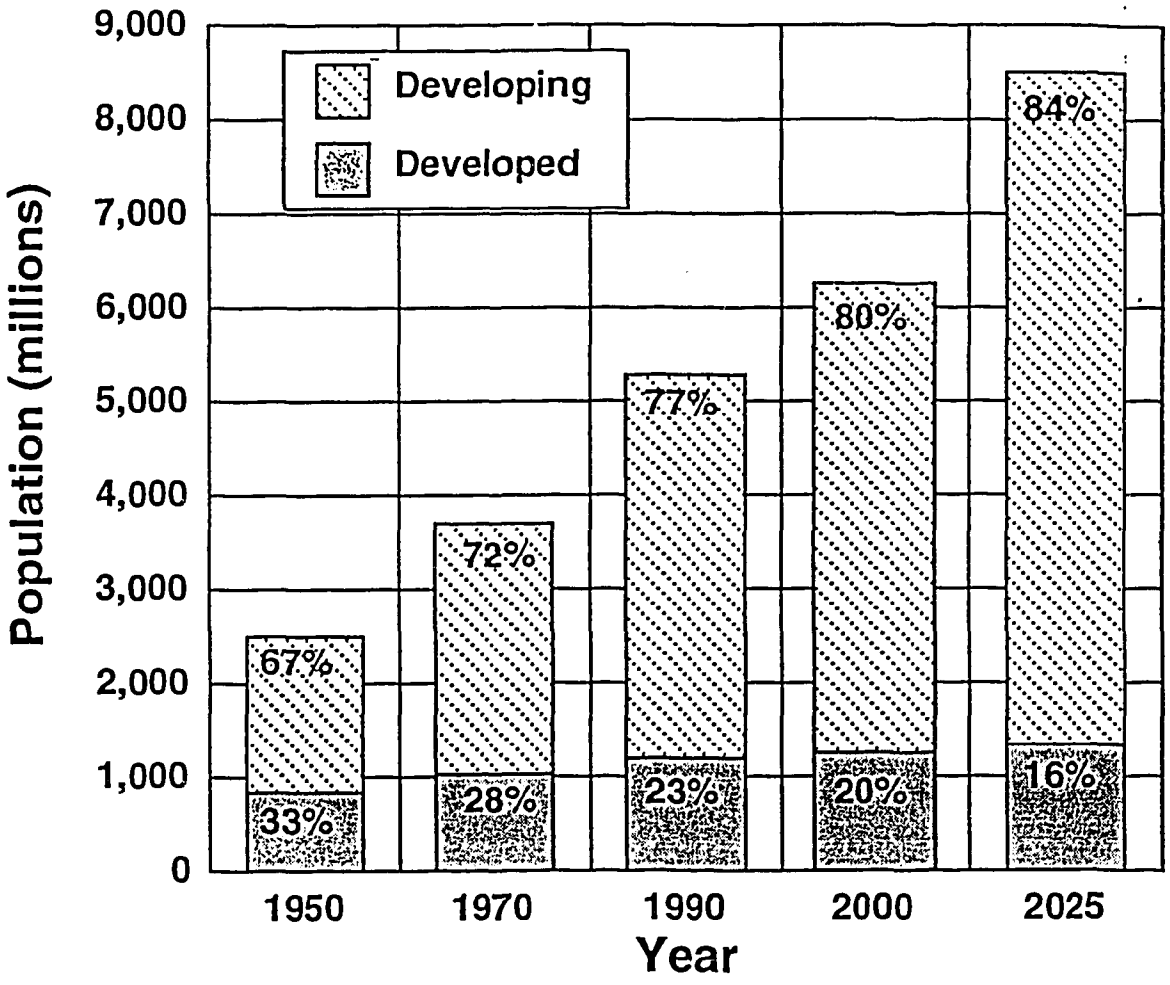

Figure 5. Population in Developed and Developing Regions of the World

Source: World Population Prospects, 1990 (United Nations)

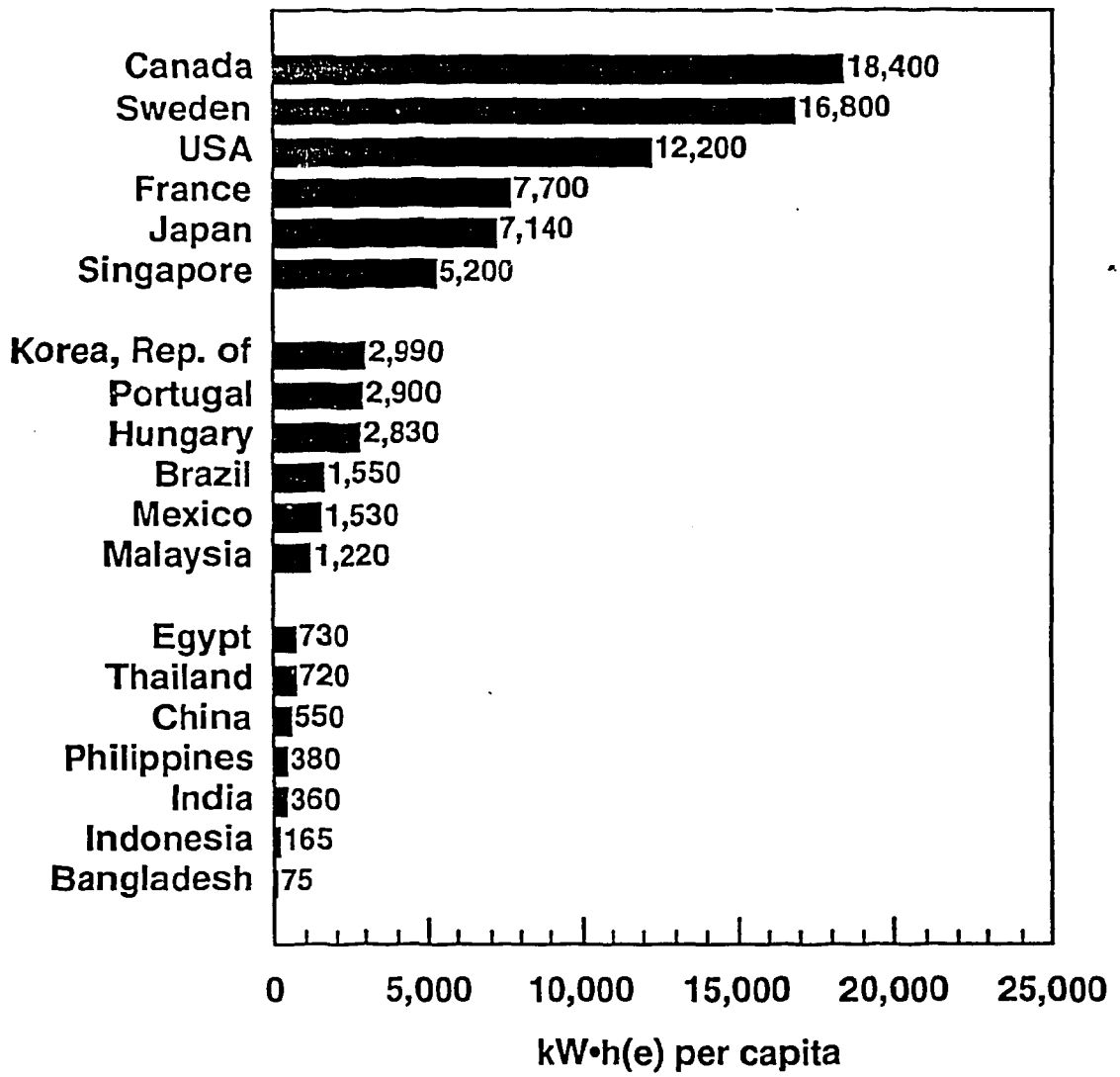

Figure 6. Electricity Consumption in 1991 (kW•h/capita)

Source: IAEA Energy and Economic Data Bank (EEDB)

Table 5. Nuclear Capacity Projections (GWe) to 2015, by Region
(Source: IAEA Reference Data Series No. 1, 1994 Edition)

Region	1993	1995	2000	2005	2010	2015
North America	114.5	114.8	116.4	119.2 120.3	106.6 109.0	108.7 114.6
Latin America	2.2	2.2	4.8 5.2	4.8 6.3	4.5 8.2	5.2 9.4
Western Europe	122.7	123.2	127.0	126.6 134.0	124.7 149.5	112.2 162.1
Eastern Europe	44.5	47.8	51.2 58.9	53.5 74.9	61.7 84.8	55.3 97.9
Africa	1.8	1.8	1.8	1.8	1.8 4.8	0.9 5.7
Middle East & South Asia	1.7	1.9	3.2	3.2 5.0	4.0 7.3	5.8 9.1
Southeast Asia & Pacific	0.0	0.0	0.0	0.0 0.6	0.0 2.2	0.0 6.4
Far East	51.3	53.9	65.1 66.7	79.0 86.7	90.5 105.9	99.4 126.1
World Total	338.7	345.6	370 379	388 430	394 472	388 531

Note: When two figures are given, the upper and lower figures are 'low' and 'high' estimates, respectively.

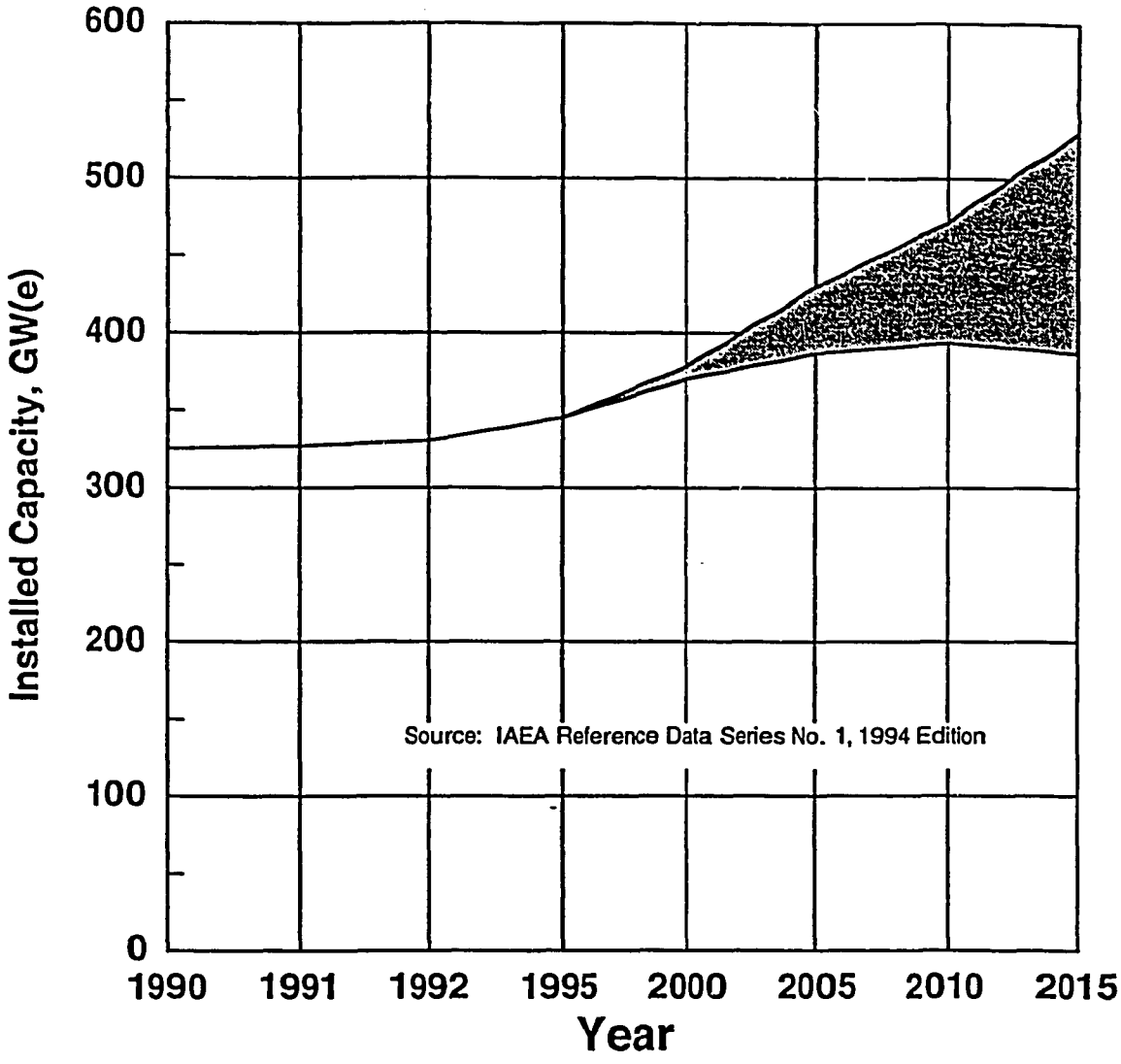

Figure 7. Projected Worldwide Nuclear Power Capacity