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THE CURRENT AND PROSPECTIVE ROLE OF NUCLEAR POWER IN WORLD ENERGY SUPPLIES

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THE CURRENT AND PROSPECTIVE ROLE OF NUCLEAR POWER IN WORLD ENERGY SUPPLIES

1. CURRENT STATUS OF NUCLEAR POWER PROGRAMMES

The statistics reported to the Agency show that nuclear energy already plays a significant role within the energy supply system of numerous countries.

During 1983, the total installed nuclear power capacity in the world increased by 10%, and, as shown in Table 1, at the end of December 1983 there were 317 nuclear power units with a total capacity of 191 GW(e) in operation in 25 countries. These nuclear units represented over 8% of the worldwide electrical power capacity and provided about 12% of the total electricity generated during 1983. A further 209 nuclear units with a total capacity of 194 GW(e) were under construction at the end of 1983; during 1983 construction was started on 23 new units with a total capacity of 17.5 GW(e).

The importance of the already-achieved supply contribution by nuclear power can be seen in perspective by noting that if the 1000 TWh of electricity produced by nuclear power plants during 1983 had been produced by fossil-fuel-fired plants, these plants would have burned fuels equivalent to about 230 million tonnes oil equivalent (MTOE) annually (that is, about 4 million barrels a day); in other words, during 1983 nuclear power plants saved fossil fuels equivalent to around 6% of the world oil production.

Although, the present status naturally varies greatly from country to country, in a number of countries the nuclear share in electricity generation is very significant. Table 2 lists 15 countries in which during 1983 nuclear power contributed more than 10% of the total electricity production. In seven of these, the nuclear share was greater than 25%.

A negative aspect of nuclear power development in the last several years has been the lack of new orders for additional nuclear power units and the cancellation or postponement of units which were ordered earlier, including some already under construction. This trend continued during 1983, as construction was started on only 23 new units (17.5 GW(e)) and contracts or firm plans for 12 units [13.5 GW(e)] were cancelled or indefinitely suspended.

Table 3 shows the growth in nuclear power capacity which is planned to take place up to 1990 as plants under construction, or scheduled to begin construction soon, are completed. It can be seen that among the Western countries, France, the Federal Republic of Germany, Japan, Spain and the USA are expecting rapid expansions in their nuclear power capacities. Also, the Soviet Union and most of the centrally planned economy (CPE) countries of Eastern Europe are vigorously building nuclear plants and are planning a fast growth of nuclear electricity production. It should be noted that the Soviet Union is constructing nuclear district heating plants for the cities of Gorki and Voronesh and a co-generation plant for Odessa.

During the 1990's the nuclear share of electricity generation in some countries will reach very impressive levels. In particular, France is planning to satisfy 70% of its electricity needs in 1990 through nuclear power. Estimated nuclear shares of electricity generation in other countries in 1990 are: over 50% in Belgium; over 40% in Bulgaria, Sweden and Taiwan; over 30% in the Federal Republic of Germany, Hungary, the Republic of Korea and Spain and between 20% and 30% in Finland, Switzerland and the USA.

How about the nuclear situation in developing countries?

As seen in Table 4 and Figure 1, at the end of 1983 only seven developing countries[x], namely Argentina, Brazil, India, the Republic of Korea, Pakistan, Taiwan and Yugoslavia, had 17 nuclear power units in operation with a total capacity of more than 8 GW(e), providing 2.3% of the total electricity generation in developing countries. By comparison, for the total world, nuclear energy contributed about 12% of total eclectricity generation. At the end of 1983, as shown in Table 4, an additional 21 units with more than 13 GW(e) capacity were under construction in most of these seven countries plus the People's Republic of China, Cuba, Mexico and the Philippines.

At least three other countries (Egypt, Turkey, Libya) have plants in the planning stage.

Some other countries, including Bangladesh, Greece, Indonesia, Portugal, Syria, Thailand and Tunisia have stated their intention to introduce nuclear power, but have not yet made definite commitments to nuclear power plant construction, mainly due to financing problems.

Figure 2 shows the increase up to 1990 in the number of countries with operating nuclear power plants, showing clearly that this will be mainly in the developing countries. Only one industrialized country will put its first nuclear power plant into service during this period, while 4 developing countries (People's Republic of China, Cuba, Mexico, the Philippines) outside CPE-Europe have their first nuclear power units under construction with scheduled start-up in this period, and Egypt has announced plans to have its first unit in operation by 1990. In addition, two developing countries within CPE-Europe

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x Unless otherwise noted, the term "developing countries" does not include developing countries (namely, Bulgaria, Czechoslovakia, Hungary, Poland and Romania) in Eastern Europe with centrally planned economies (CPE-Europe).

(Poland and Romania) are constructing their first nuclear units, with scheduled start-up before 1990.

In spite of this increase in the number of developing countries using nuclear power, most of the growth in nuclear power capacity will be in the industrialized countries.

2. NUCLEAR POWER PROSPECTS TO 2000

In the longer term up to the year 2000, there are expectations that a resumption in economic growth will stimulate growth in energy and electricity needs, and that nuclear plant ordering will be resumed in countries where it has been suspended. Additional incentives for an increased demand for nuclear energy would include: a growing recognition that nuclear energy is increasingly able to replace fossil fuel not only for electricity generation but also for heat applications; a restored public and political confidence in nuclear energy as a reliable, economic and environmentally acceptable source of energy; and the foreseeable need to replace a significant amount of older generating capacity.

Based on the information available to the IAEA, the prospects for nuclear power capacity growth to the year 2000 have been estimated as shown in Table 5 together with very rough estimates of the nuclear share in total electricity production. It must be emphasized that the estimates are subject to large uncertainties.

For developing countries, as shown in Table 5, it is projected that by the year 2000 the nuclear capacity could reach 65 to 105 GW(e); that is, a two-fold to three-fold increase over the capacity expected to be operating in 1990. As shown in Table 6, this expansion will take place mostly in the 17 developing countries which at the end of 1983 already had nuclear power plants in operation or under construction.

An additional 5 to 15 GW(e) of capacity might, under optimistic assumptions, be brought into service in a few additional developing countries which may consider having nuclear power plants in operation by the year 2000, including Egypt, and the OECD countries (Greece, Portugal and Turkey) which are developing plans to introduce nuclear power into their electricity supply systems and may have a total nuclear capacity up to 7 GW(e) in operation by the year 2000 according to a recent projection published by the OECD Nuclear Energy Agency.

In the case of the industrialized countries, the nuclear power capacity is projected to increase by about 50% between 1990 and 2000; about 85% of the world's nuclear power capacity in the year 2000 would be in industrialized countries. The very few industrialized countries which currently have no nuclear power projections logically will consider nuclear as one option to satisfy part of their long-term energy needs, even though they have made no clear commitments to start any nuclear power plants in the near future. In most cases, this reflects the fact that these countries are well endowed with other energy resources, like Australia (coal) or Norway (hydro).

3. THE SPECIAL DIFFICULTIES IN DEVELOPING COUNTRIES

An important factor limiting the possible introduction of nuclear power in a larger number of developing countries has in most cases been their small and fragmented transmission grids and the present unavailability of proven nuclear power plants in a size range of 200 to 400 MW(e) which could be used in these grids, with the exception of the USSR standardized 440 MW(e) PWR type, which is still built and exported.

Also, in spite of the expected growth, the majority of developing countries have and will continue to have very low electricity consumption levels.

As can be seen in Table 7 eight developing countries accounted for about 62% of the total electricity production in the developing world during 1981. All have on-going nuclear power programmes. The remaining 38% of electricity production was distributed among 153 countries, with an average of 2.8 TWh per country.

The total electricity production of all 161 developing countries of around 1300 TWh corresponds to only around 50% of the electricity produced in the USA in 1981.

A generally used, but also a rather simplified, rule-of-thumb is that a single power generating unit should not exceed 10% of the total generating capacity of all plants on the transmission grid, for reasons of stability of the electricity supply. If one applies this rule to Member States of the IAEA, the number of countries which would be able to use nuclear power plants in various size ranges are presented in <u>Figure 3</u>.

- At present, the power grids in 37 IAEA Member States could accept nuclear units of 600 - 1300 MW(e) now available on the market whereas only 24 actually have operating power plants.

- Some 15 countries, all developing, could use units in the 200-600 MW(e) ranges as their biggest units.

This seems to be one indication of the potential market for smaller nuclear power plants, if they were economically competitive and more widely available, but this also applies for other types of power plants.

However, poor economics, the limited availability of mature designs and other, mostly technical, uncertainties in the decision-making process have kept suppliers' and buyers' interests in small and medium power reactors (SMPRs) at a rather modest level.

To assist in this area and bridge existing information gaps, the IAEA has started a study which brings together the three major partners in any future SMPR plant, namely buyers, suppliers and financing institutions. This study is intended to analyse the technical and economic grounds for SMPRs and to identify the size of the possible market for this type of nuclear power plant in the future.

It should, however, be recognized that going nuclear with a small reactor will require nearly the same commitments to a high technology as in the large reactor case, namely in respect of manpower, infrastructure, transfer of technology and financing

Nuclear power is a capital-intensive energy source with nuclear power plant investment costs contributing up to 80% of the total nuclear generation costs. The total investment for a 600 - 900 MW(e) nuclear power plant might be between 1.5 and 3.0 billion US$, that is, between 2500 and 3500 US$/kW(e) installed capacity, depending on costs for development of the infrastructure, including expansion of the transmission and distribution system and a possible transition to a higher voltage level.

Because of the high investment requirements, financing proves presently to be a very important limiting factor for nuclear power programmes, particularly in developing countries where the present economic situation is extremely precarious. It is particularly unfortunate that those developing countries which will need nuclear power and which have - or are close to having - the infrastructure needed to support a nuclear power programme are now in such dire financial straits that their nuclear projects have to be delayed or cancelled.

It must also be recognized that the nuclear power programme is only one of several development programmes which will compete for the available investment funds, and development of nuclear power should not exclude the possibility of other options and technologies appropriate to a specific country.

Among the developing countries with on-going nuclear power programmes, Mexico is possibly the most outstanding example where financing constraints have seriously affected the country's nuclear power programme. The effect of financing constraints has also caused substantial delays in the programmes of other countries, such as Brazil, Romania and Yugoslavia. Bangladesh, Egypt and Turkey are examples of developing countries where the effective initiation of their first nuclear power project seems to depend mainly on finding satisfactory financing arrangements. In fact, there is hardly a

country (either developing or industrialized) whose nuclear power programme has not been affected negatively by this problem, especially during the recent period of worldwide economic recession.

So far, nearly all imported nuclear power plants in developing countries were financed through special bilateral arrangements between the supplier and buyer. However, the present economic situation makes it difficult for the ever-increasing investment costs to be financed by only one supplier under acceptable conditions for the buyer. The sometimes very favourable financing previously available from suppliers seems to be no longer available, and it appears that the suppliers now have to seek international cooperation to obtain financing.

A closer co-operation between industrialized countries might be a possible solution by sharing supply of components and financing guarantees between at least two or more industrialized countries, as the present multilateral negotiations for the first nuclear power plant in Turkey illustrate.

On the other hand, international financing, e.g. by the World Bank, can realistically not be expected to a large extent within the foreseeable future. As a result, many nuclear projects in developing countries will be delayed for a considerable time due to financing problems, and multilateral financing might be the only solution to the problem.

4. ECONOMIC PERFROMANCE OF NUCLEAR POWER

In this context, the economic competitive situation of nuclear power should be briefly summarized, considering that the costs of constructing nuclear power plants have risen very rapidly during the past decade.

It must be emphasized that inter-fuel comparisons (nuclear versus fossil), at either national or international level, have only limited "generic" value due to the number of assumptions and operating conditions that are behind each example. Any answers depend on specific conditions and economic parameters adopted. Nevertheless, in general it can be stated that nuclear power plants of the sizes presently on the market are and will continue to

be economically competitive with oil-fired plants. In fact, the economic advantage of the nuclear power plants over oil-fired plants is overwhelming, given the present level of international oil process.

In comparing electricity costs from nuclear and coal-fired power plants, the results depend on a number of factors, and there is no single global answer. However, in most situations large nuclear power plants becoming operational in the near future, can produce electricity cheaper than coal-fired power plants. In some special situations, however, such as in areas of the USA and Canada with low-cost coal available to plants at nearby or mine-mouth locations, coal-fired power plants can deliver electricity at costs competitive with or lower than nuclear plants. The key economic factor for coal-generated electricity is the cost of coal delivered to the power station. For nuclear power, the key factor is the total capital investment cost, which is significantly increased when interest rates are high and lead times long. For coal fired plants, stringent environmental protection regulations are expected to be applied in the future. These will increase their capital and operational costs, placing nuclear power in a more competitive position.

National papers presented during the September 1982 IAEA Conference on Nuclear Power Experience confirmed the generally positive experience from some 2600 accumulated reactor-years of nuclear power plant operation up to mid-1982[x]. Several countries, notably Belgium, stressed the importance of nuclear generation, when it has reached a significant level in a country, in keeping constant or even decreasing electric energy prices.

Although the load factors of base-loaded nuclear power plants are somewhat lower than the expected value used for planning purposes, experience has confirmed the expectation that nuclear plants would produce cost savings in comparison with coal- or oil-fired plants in most countries. In the reporting countries, it was clearly documented that nuclear plants are by a considerable margin the economic choice over oil-fired power plants and, except in certain regions where coal is abundant and cheap, also over coal-fired power plants.

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x The accumulated experience by the end of 1982 was 2836 reactor-years and by the end of 1983 3160 reactor-years.

This conclusion is supported also by IAEA studies of projected generation costs for nuclear power plants larger than 600 MW(e) capacity. As shown in Figure 4, in this size range nuclear plants are estimated to have generation costs substantially lower than oil-fired plants, and are economically competitive with coal-fired plants except in the case of low coal prices.

There is no currently available information which would provide reliable cost data for new nuclear power reactor projects in the size range below about 600 MW(e). However, the IAEA has some data from potential suppliers of small and medium power reactors (SMPR), providing rather rough cost estimates in the size range between 200 and 400 MW(e). These data lead to generation cost estimates, shown also in Figure 4, indicating that nuclear power plants within this size range might be competitive with oil-fired plants, which will remain the most important source for electricity generation in the majority of developing countries.

In comparison with the electricity generation costs of coal-fired power plants, nuclear plants appear only marginally competitive in sizes as small as about 300 to 400 MW(e), and only when the coal price is high. It should, however, be noted that a large expansion of electricity generation with coal-fired plants in developing countries would also require large investments for the necessary infrastructure, especially transportation systems; these costs have not been included in this analysis. The environmental impact of a large coal programme also would have to be taken into consideration.

In light of these rather encouraging preliminary results with regard to SMPR's, the Agency has started a study to more precisely determine the probable costs and economic competitiveness of SMPR's, and to identify the possible market for this type of nuclear power plants in the future.

4.1 Components of Nuclear Power Generation Costs

The main components entering into the calculation of nuclear power generation costs are listed in Table 8. The basic elements are capital investment, nuclear fuel cycle, and operating and maintenance (O&M) costs. Table 9 shows

some indicative values for the percentage contribution of each of these elements to the total cost of electricity production.

Additionally, infrastructure development costs, such as R&D and transfer of technology from developed countries, domestic industrial and manpower development associated with a nuclear power programme, should be factored in. However, it should be considered that there are also national benefits in the development of such activities. Plant performance is reflected in its load factor, power rating and economic life; the economy of the country is reflected through domestic and foreign interest, escalation and discount rates used in the analysis.

<u>Nuclear Plant Capital Costs</u>. Due to its large contribution to total cost of nuclear power, the capital investment cost of nuclear plants deserves particular attention.

One of the most dominant factors in the changing costs of nuclear power during the last several years has been the sharp increase, in most countries, of plant investment costs.

One of the major contributions to the increases in the capital costs (in constant money) has been attributed to the changes in regulatory requirements in some countries and the consequently required changes in designs, increases in scope of supply, and backfitting during execution of projects. In addition to their direct costs, all these factors will cause lengthened project times, resulting in very much higher charges for interest during construction, especially with the high interest rates which prevailed during the late 1970s and early 1980s.

The importance of project time and escalation rate, as driving factors in plant costs, are shown in <u>Figure 5</u>. The direct cost (sometimes referred to as "overnight" cost) of the plant is about 1.5 billion US $. If we assume a modest 5%/year real rate of cost escalation and a 6-year project time, the total investment cost, including interest and escalation during construction, is about 2.2 billion US $. That is, interest and escalation costs add about

50% to the direct costs in the case of a 6-year project time. However, at the same escalation rate, but with a 12-year project time, interest and escalation add over 200% to the direct costs!

Nuclear Fuel Costs. As was shown in Table 9, fuel costs contribute only 15-30% to the total cost of electricity from nuclear power plants. By comparison, in fossil-fuel-fired plants the cost of fuel accounts for 40-65% of the total generation cost for coal-fired plants and up to 85% for oil-fired plants.

The major components of the fuel cycle cost for a light-water reactor (LWR) using enriched uranium as fuel are shown in Figure 6. Reference data for this illustrative case are listed in Table 10. It is of interest to examine the sensitivity of the nuclear fuel cycle cost, and the total nuclear generation cost, to possible future changes in these major components. Results from such a sensitivity analysis are shown in Figure 7.

Effect of changes in uranium price (reference case value: US $ 25/lb U_3O_8). It can be seen that if the uranium price were doubled (that is, a 100% increase), the total nuclear fuel cycle cost would increase by 27%. However, as the fuel cycle contributes only about 15-30% to the total generation cost, the assumed 100% increase in uranium price would increase nuclear generation costs by only about 4-8%. By comparison, a 100% increase in fossil-fuel prices would increase generation costs by about 40 - 65% for coal-fired plants and about 70-85% for oil-fired plants.

Thus, it is clear to see that, once a nuclear power plant is built, the future generation costs are much less sensitive to changes in fuel prices than in the case of fossil-fuel-fired plants.

Effect of changes in enrichment price (reference case value: US $ 140/SWU). The results are similar to those already discussed for uranium prices. A 100% increase in enrichment price would lead to about 38% increase in fuel cycle costs, resulting in only about 6-11% increase in total generation costs.

Effect of changes in back-end costs (reference case value: US$ 800/ kg fuel). The third major component of the LWR nuclear fuel cycle is the cost of managing the spent fuel, which includes reprocessing and waste disposal – the so-called "back-end" of the fuel cycle. As shown in Figure 7, a 100% increase in the back end costs would lead to about 24% increase in fuel cycle costs, resulting in only about 4-7% increase in total generation costs.

4.2. Other Cost Considerations

Based on the studies discussed above, the IAEA concludes that nuclear power is an economically competitive option for future energy and electricity supplies. However, the economic advantage of nuclear power depends greatly on the particular circumstances of each case; generalized figures have little applicability.

The high investment requirements and heavy front-end loading of the expenditure cycle on a nuclear power station may be a difficult burden in a developing country having to rely on relatively hard loans for a nuclear power programme.

Also, a pre-condition for the introduction of nuclear power is that the local infrastructure should be adequately developed. Creating an infrastructure into which nuclear power can be introduced may be a lengthy and costly process, but it is essential. The nuclear power option differs in this respect from other power plant alternatives where the infrastructure demands are far less stringent and also are more similar to those previously encountered.

On the other hand, the development of a coal industry, or its major expansion, is, as many countries have learned, a complicated exercise dependent on the careful planning of production and transport facilities to assure regular supplies to consuming industries. Where coal has not been previously used for power generation, a substantial front-end investment will be needed for coal transportation to the power plants, storage,

handling and ash disposal arrangements. There is little foreign investor interest in coal so that the major investments required to open new mines and expand old ones must come from domestic sources, in practice largely government. Compared with oil, coal is expensive to transport and difficult and dirty to handle, thus seriously reducing its comparative price advantage. The transport element is particularly important in imported coal. While ocean transport is not expensive on a ton-kilometer basis, the costs of inland transport are very much higher, thus limiting coal use in practice to coastal regions or to inland situations which are particularly well served by rail links. None of these problems is in and of itself insuperable, but they add up to a formidable list of constraints, the overcoming of which require a firm commitment by producing, transporting and consuming entities.

5. CONCLUSIONS

Based on the facts and considerations discussed in this paper, the IAEA concludes that nuclear power is a technologically mature and economically competitive option for future energy and electricity supplies.

Nuclear power has captured and will keep a substantial share of the world electricity market, and its use has continued to increase through years of general recession at a faster rate than that of any other significant energy source. At the global level, its future is quantitatively uncertain - as is that of all energy sources - but qualitatively secure, simply because it has become an indispensable part of the global energy supply.

The role of nuclear energy in the energy supply programme of both industrialized and developing countries is expected to grow substantially in the future. This growth is seen as essential due to the need to develop all available technologies in order to meet the continued growth in energy and electricity which will be needed by a growing and increasingly urbanized world population.

However, nuclear power is not seen as a panacea, or even a viable near-term solution, for the majority of developing countries, due to the difficulties in using this technology in small, weakly-connected electrical generation and transmission systems. Up to the year 2000, it is expected that no more than about 15 developing countries (excluding CPE-Europe countries) will be producing electricity with nuclear power plants.

Thus, the great majority of developing countries will continue to rely on oil, coal, gas, hydro and other resources for their energy supplies.

Table 1

Nuclear Power Status at the end of 1983

Country Name	In Operation		Under Construction		Electricity Supplied by Nuclear Power Reactors in 1983	
	No. of Units	Total MW(e)	No of Units	Total MW(e)	TW.h(e)	% of Total
ARGENTINA	2	935	1	692	3.4	8.8
BELGIUM	6	3473	2	2012	22.8	45.7
BRAZIL	1	626	1	1245	0.2	0.1
BULGARIA	4	1632	2	1906	12.3	32.3
CANADA	15	8303	8	5925	46.3	12.9
CHINA			1	300		
CUBA			2	816		
CZECHOSLOVAKIA	2	762	9	4354	5.7	8.0
FINLAND	4	2206			16.7	41.5
FRANCE	36	26903	25	29200	136.9	48.3
GERMAN D. R.	5	1694			(11)	(12)
GERMANY, F. R.	16	11110	11	11908	62.4	17.8
HUNGARY	1	408	3	1224	2.3	10.0
INDIA	5	1030	5	1100	2.9	(2.2)
ITALY	3	1232	3	1999	5.6	3.2
JAPAN	28	19023	10	10022	106.5	(20)
KOREA, REP. OF	3	1789	6	5474	9.0	18.4
MEXICO			2	1308		
NETHERLANDS	2	501			3.4	5.9
PAKISTAN	1	125			0.2	1.0
PHILIPPINES			1	621		
POLAND			2	880		
ROMANIA			2	1320		
SOUTH AFRICA			2	1842		
SPAIN	6	3760	9	8369	10.2	9.1
SWEDEN	10	7355	2	2100	39.1	36.9
SWITZERLAND	4	1940	1	942	14.8	29.3
TAIWAN	4	3110	2	1814	18.9	(36)
UK	35	8304	7	4252	43.9	17.0
USA	80	63315	49	54228	292.0	12.7
USSR	43	20671	41	38001	(113)	(8)
YUGOSLAVIA	1	632			3.7	5.8
World Total	317	190839	209	193854	(1000)	(12)

Note: Values in parentheses are IAEA estimates

Source, IAEA PRIS, Report XBLMQ70

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TABLE 2

LEADING COUNTRIES IN NUCLEAR SHARE OF TOTAL ELECTRICITY PRODUCED DURING 1983

Country	1983 Nuclear Share, %
FRANCE	48.3
BELGIUM	45.7
FINLAND	41.5
SWEDEN	36.9
TAIWAN	(36)[x]
BULGARIA	32.3
SWITZERLAND	29.3
JAPAN	(20)[x]
KOREA, REPUBLIC OF	18.4
GERMANY, FED. REP.	17.8
UNITED KINGDOM	17.0
CANADA	12.9
UNITED STATES	12.7
GERMAN DEM. REP.	(12)[x]
HUNGARY	10

SOURCE: IAEA Power Reactor Information System (PRIS)

x IAEA Estimates

Table 3. Estimated Expansions of Nuclear Power Capacity up to 1990

Country	GW(e) in operation at End of Year 1983 (actual)	1985 (1) (estimate)	1990 (1) (estimate)
North America			
Canada	8.3	10.0–10.8	14.2–15.1
USA	63.3	83.3–90.0	110–111
Sub-total	71.6	93.3–100.8	124.2–126.1
Western Europe			
Belgium	3.5	5.5	5.5
Finland	2.2	2.2	2.2
France	26.9	36.6–40.3	56.1–58.8
Germany, Fed. Rep.	11.1	16.2–16.5	23.0–24.3
Italy	1.2	1.3	3.2
Netherlands	0.5	0.5	0.5
Spain	3.8	5.6	5.6
Sweden	7.4	8.4–9.5	9.5
Switzerland	1.9	2.9	2.9
United Kingdom	8.3	10.1	12.6
Sub-total	66.8	89.3–94.4	120.8–125.1
Eastern Europe 2/ (incl. Asian part of USSR)			
Bulgaria	1.6	1.6–2.6	3.5
Czechoslovakia	0.8	2.0–2.4	4.1–5.0
German Dem. Rep.	1.7	1.7	1.7
Hungary	0.4	0.8–1.2	1.6
Poland	–	–	0–0.4
Romania	–	–	1.3
USSR	20.7	27.6–29.2	58.7–74.9
Yugoslavia	0.6	0.6	0.6
Sub-total	25.8	34.4–37.7	71.5–89.0

Table 3 (continued). Estimated Expansions of Nuclear Power Capacity up to 1990

Country	GW(e) in operation at End of Year 1983 (actual)	1985[1] (estimate)	1990[1] (estimate)
Industrialized Pacific			
Japan	19.0	22.8–24.7	27.9–31.7
Sub-total	19.0	22.8–24.7	27.9–31.7
Asia			
China, P.R.	–	–	0.3
India	1.0	1.3	1.7–2.1
Korea, Rep. of	1.8	3.6–5.4	6.8–9.0
Pakistan	0.1	0.1	0.1
Philippines	–	0.6	0.6
Taiwan	3.1	4.0–4.9	4.9
Sub-total	6.0	9.6–12.3	14.4–17.0
Latin America			
Argentina	0.9	0.9	1.6
Brazil	0.6	0.6	1.9–3.1
Cuba	–	–	0.8
Mexico	–	–	1.3
Sub-total	1.5	1.5	5.6–6.8
Africa & Middle East			
Egypt	–	–	0–0.9
South Africa	–	1.8	1.8
Sub-total	–	1.8	1.8–2.7

Table 3 (continued). Estimated Expansions of Nuclear Power Capacity up to 1990

Country Grouping	GW(e) in operation at End of Year 1983 (actual)	1985[1] (estimate)	1990[1] (estimate)
Industrialized Countries	179.8	236.5-252.6	335.1-361.3
Developing Countries			
a) In CPE-Europe[3]	2.8	4.4-6.2	10.5-11.8
b) Others[4]	8.1	11.7-14.4	20.6-25.3
c) Total of DC's	10.9	16.1-20.6	31.1-37.1
Worl Total (rounded)	191	253-273	366-398

Source: IAEA Power Reactor Information System (PRIS).

Notes:

1. The lower values for operating capacities are estimated by assuming that no planned reactors not yet under construction will achieve grid connection during this period and that half of the capacity scheduled to achieve grid connection in a given year will slip to the next year.

   The high case values are estimated by assuming that all reactors under construction and all planned reactors will achieve grid connection exactly as currently scheduled.

2. Capacity figures for Eastern Europe countries in 1990 are IAEA estimates based on project information, which is, however, not complete. The official target for Eastern Europe is about 100 GW(e) in 1990.

3. Developing countries in the Centrally Planned Economies (CPE) in Europe: Bulgaria, Czechoslovakia, Hungary, Poland and Romania.

4. Other developing countries: Argentina, Brazil, People's Republic of China, Cuba, India, Republic of Korea, Mexico, Pakistan, Philippines, Taiwan and Yugoslavia.

TABLE 4

NUCLEAR POWER PLANTS IN DEVELOPING COUNTRIES[x]

(AS OF 31 DECEMBER 1983)

COUNTRY	OPERATING		UNDER CONSTRUCTION	
	NO. OF UNITS	CAPACITY MW(E)	NO. OF UNITS	CAPACITY MW(E)
ARGENTINA	2	935	1	692
BRAZIL	1	626	1	1,245
CHINA, P.R.	–	–	1	300
CUBA	–	–	2	816
INDIA	5	1,030	5	1,100
IRAN, ISL. REP.			(SEE NOTE 1)	
KOREA, REP. OF	3	1,789	6	5,474
MEXICO	--	--	2	1,308
PAKISTAN	1	125	–	--
PHILIPPINES	–	--	1	621
TAIWAN	4	3,110	2	1,814
YUGOSLAVIA	1	632	–	–
TOTAL	17	8,247	21	13,370

x Not including Those In The Centrally Planned Economies (CPE) in Europe.

NOTE 1: In the Islamic Republic of Iran, Construction on 4 units has been suspended, but resumption of work on 2 units is under negotiation.

SOURCE: IAEA Power Reactor Information System (PRIS).

Table 5. Prospects for Growth in Nuclear Power Capacity and Nuclear Share of Total Electricity, up to the Year 2000.

Region	1985		1990		2000	
	GW(e)	% of elec.	GW(e)	% of elec.	GW(e)	% of elec.
North America	93–101	17	124–126	20	130–160	20
Western Europe	89–94	28	121–125	35	130–190	40
Eastern Europe (incl.Asian part of USSR)	34–38	11	72–89	16	140–240	28
Industrialized Pacific	23–25	17	28–32	17	40–60	25
Asia	10–12	5	14–17	6	30–45	8
Latin America	1.5	2	6–7	4	10–15	6
Africa and Middle East	1.8	3	1.8–2.7	2	5–15	6
World Total	253–273	15	366–398	18	485–725	20
Industrialized Countries	236–253	18	335–361	23	420–620	25
Developing Countries						
a. In CPE Europe	4–6	9	10–12	15	25–35	18
b. Others	12–14	3	21–25	4	40–70	6
c. Total	16–20	4	31–37	6	65–105	8

Note: See notes (1 and 2) of Table 3 for explanation of capacity figures for 1985 and 1990. Capacity figures for 2000 are IAEA projections.

Table 6. Developing Countries Included in Year 2000 Nuclear Power Capacity Projection

Countries with nuclear plants in operation or under construction at end of 1983		Additional countries which may consider having nuclear plants in operation by 2000	
Argentina	Mexico	Algeria	Libyan Arab J.
Brazil	Pakistan	Bangladesh	Malaysia
Bulgaria	Philippines	Chile	Portugal
China, P.R.	Poland	Egypt	Saudi Arabia
Cuba	Romania	Greece	Syrian Arab Rep.
Czechoslovakia	Taiwan	Indonesia	Thailand
Hungary	Yugoslavia	Iraq	Turkey
India		Korea, Dem. Rep.	Venezuela
Iran, Isl. Rep.[x]			
Korea, Rep. of			
Nuclear Capacity Estimated for 2000: 60-90 GW(e) in 17 countries		5-15 GW(e) in 5 to 10 countries	

x Construction of 4 nuclear power units has been stopped, but resumption of work on 2 units is under negotiation.

Table 7

ELECTRICITY PRODUCTION IN DEVELOPING COUNTRIES[x] DURING 1981

		ELECTRICITY PRODUCTION TWH(E)	PERCENT OF TOTAL PRODUCTION IN DC'S
1.	CHINA, PEOPLE'S REP. OF	309	23
2.	BRAZIL	140	11
3.	INDIA	117	9
4.	MEXICO	74	6
5.	YUGOSLAVIA	57	4
6.	KOREA, REP. OF	43	3
7.	TAIWAN	42	3
8.	ARGENTINA	38	3
	SUB-TOTAL	820	62
	TOTAL ALL OTHERS (153 COUNTRIES)	502	38
TOTAL DEVELOPING COUNTRIES (161 COUNTRIES)		1,322	100

x NOT INCLUDING THOSE IN THE CENTRALLY PLANNED ECONOMIES (CPE) IN EUROPE.

SOURCE: IAEA ENERGY AND ECONOMIC DATA BANK (EEDB).

Table 8

MAIN COMPONENTS AND INFLUENCING FACTORS OF NUCLEAR POWER PLANT ECONOMICS

Components:

Capital investment costs

Fuel cost

Operating and maintenance cost

Influencing Factors

Infrastructure development costs

Plant construction duration

Plant load factor

Plant net electric power rating

Plant economic life

Interest rate (foreign and local)

Escalation rate (foreign and local)

Discount rate (national economy)

Table 9

PERCENTAGE DISTRIBUTION OF ELECTRICITY GENERATING COST

	Nuclear	Coal	Oil
Capital	55–80%	25–55%	10–25%
Fuel	15–30%	40–65%	70–85%
O & M	5–15%	5–10%	5%
TOTAL	100%	100%	100%

Table 10

REFERENCE PARAMETERS FOR LWR FUEL CYCLE COST

Parameter		Base value
Reactor load factor,	%	70
Natural uranium price,	US$/lb U_3O_8	25
Conversion price,	US$/kg U	6
Enrichment price,	US$/SWU	140
Fabrication[x],	US$/kg U	175
Back-end cost,	US$/kg fuel	800
Plutonium credit,	US$/g	0

x Includes fresh fuel shipping cost.

Figure 1 (a)

Nuclear Share of Total Electricity Generation
In Developing Countries during 1983
(Percent of Total)

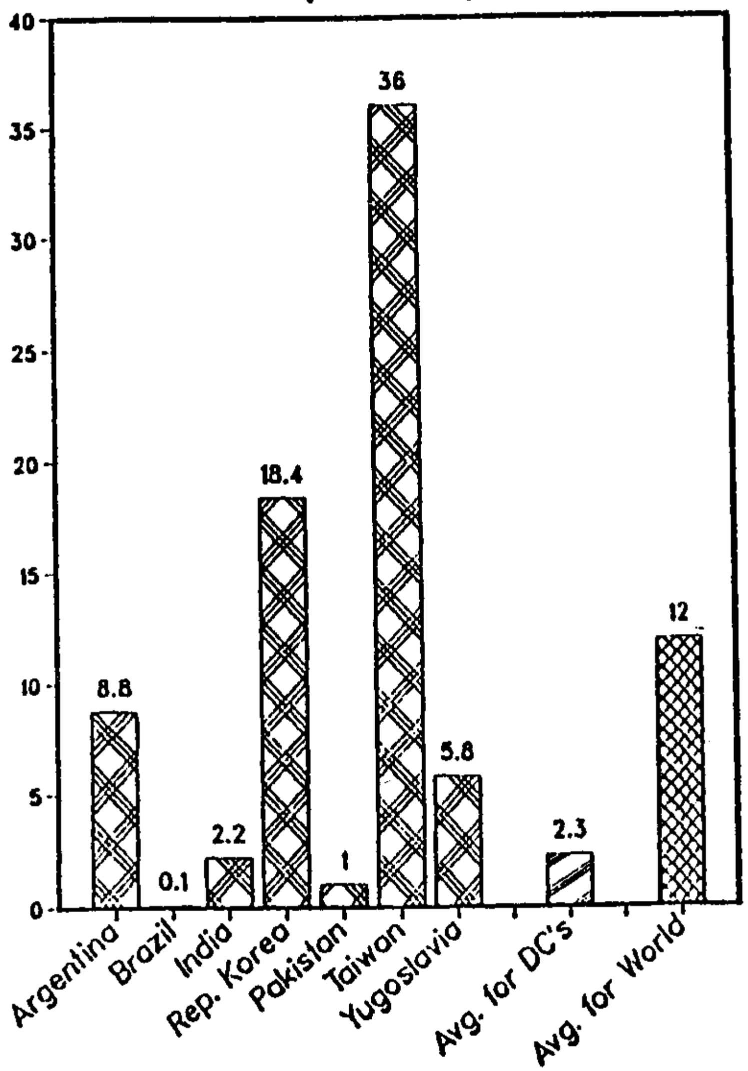


Figure 1 (b)

Power Reactors in Operation
As of Dec. 1983

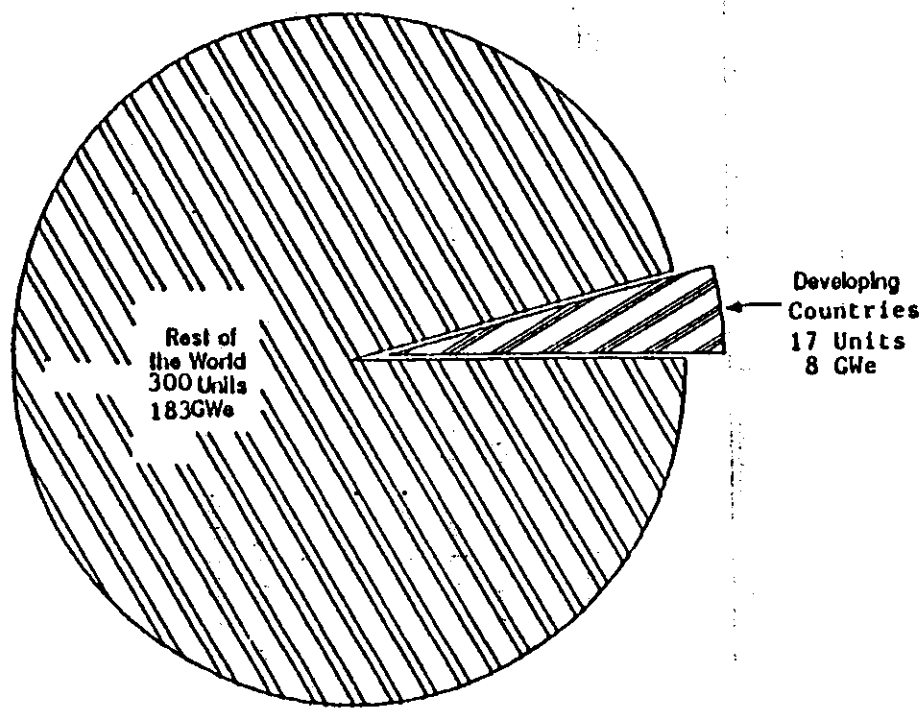
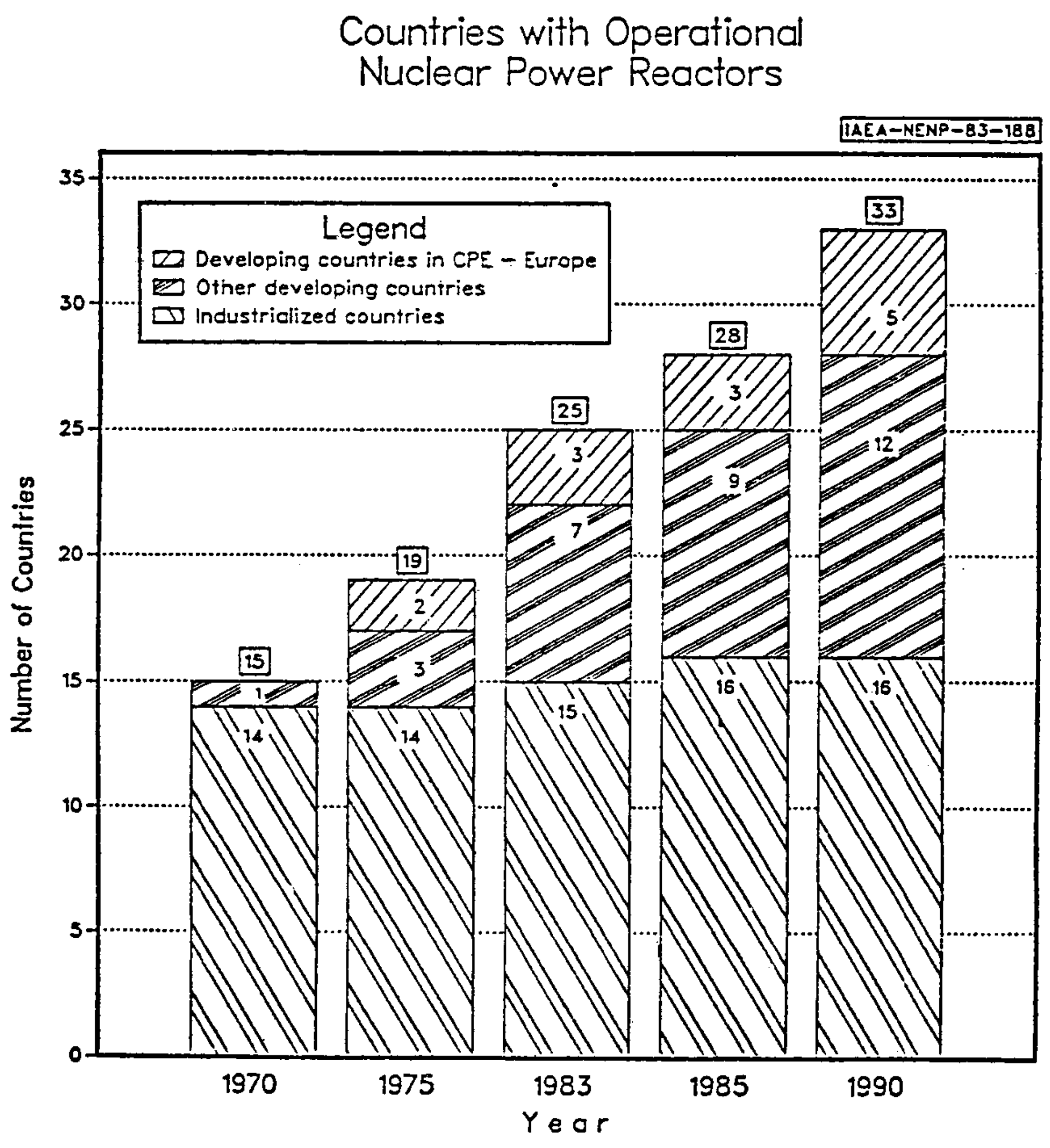


Figure 2



Source: IAEA Power Reactor Information System

Source: IAEA Economic and Energy Data Bank

Figure 3

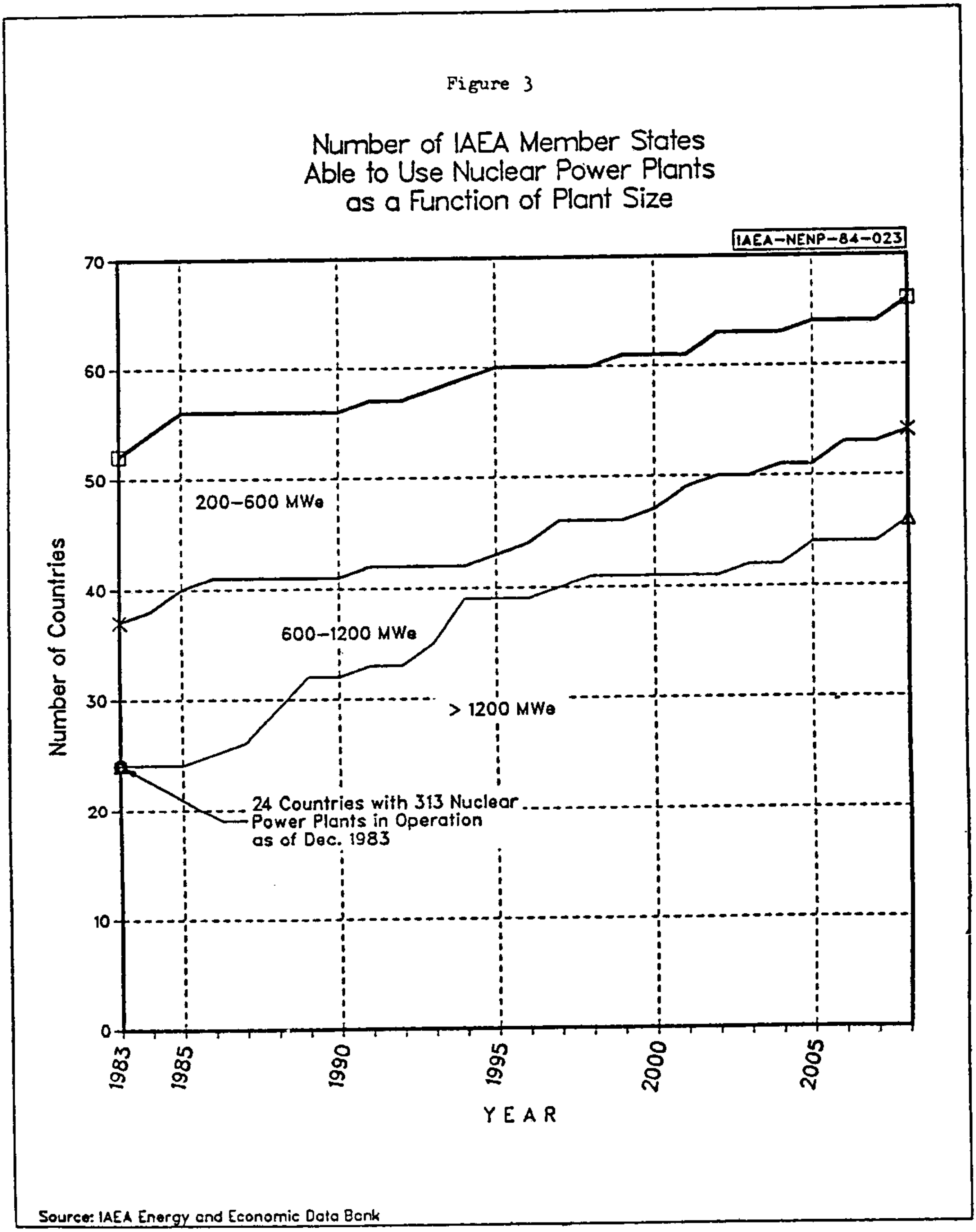
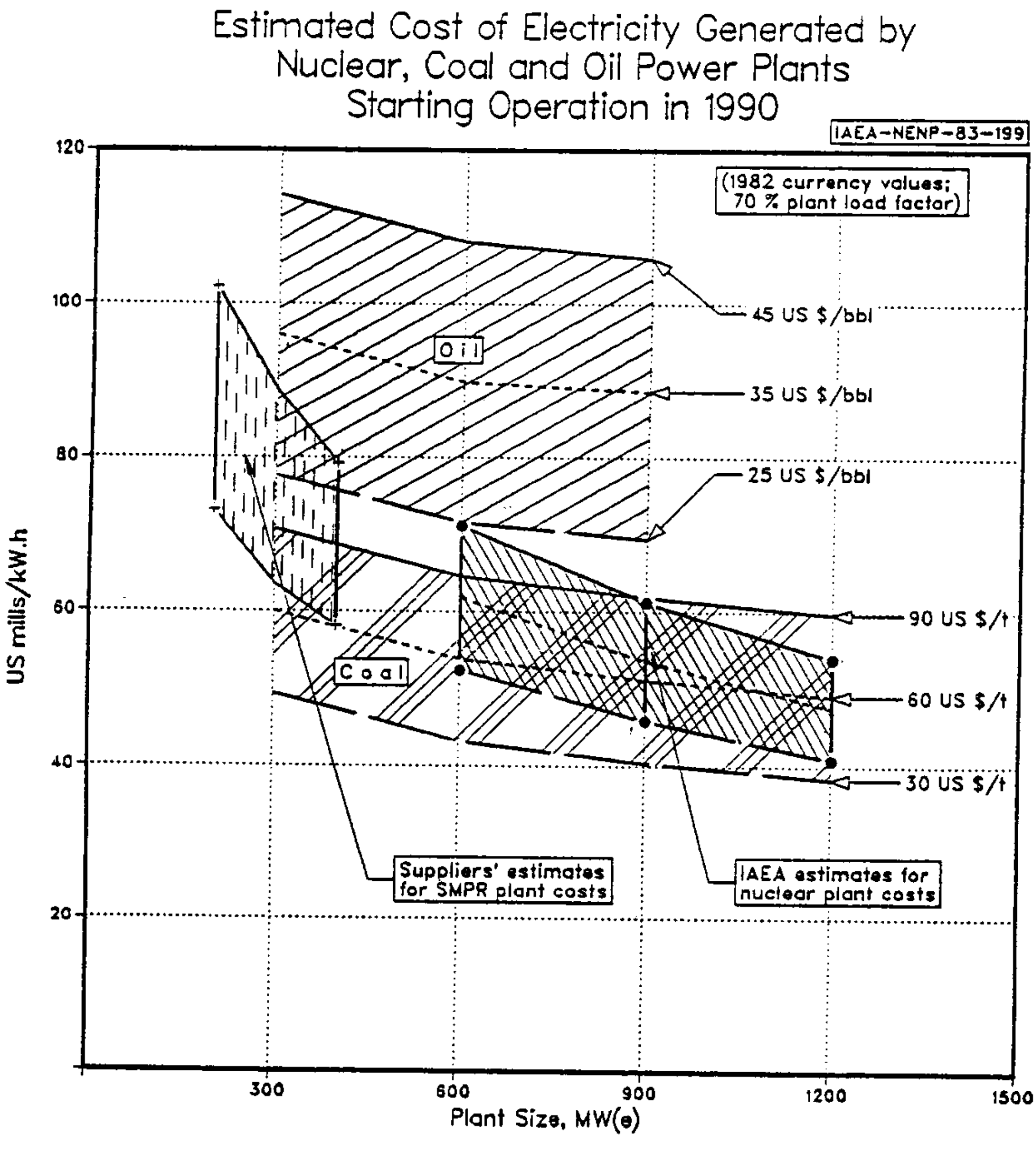
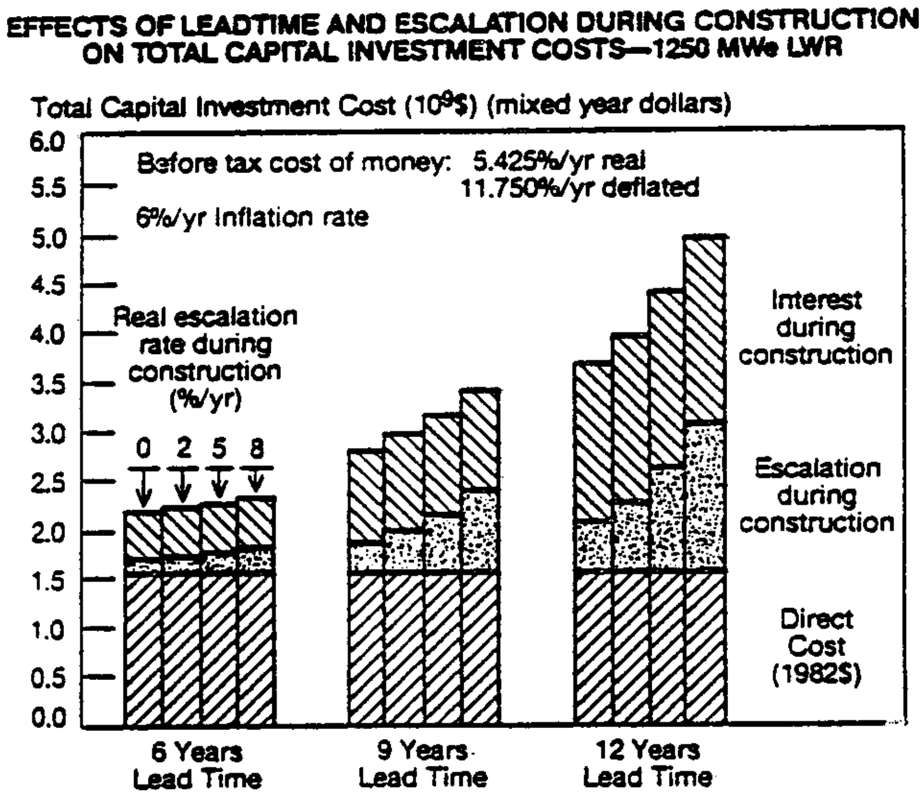

Number of IAEA Member States
Able to Use Nuclear Power Plants
as a Function of Plant Size
IAEA-NENP-84-023
70
60
50
40
30
20
10
0
Number of Countries
200-600 MWe
600-1200 MWe
> 1200 MWe
24 Countries with 313 Nuclear
Power Plants in Operation
as of Dec. 1983
1983
1985
1990
1995
2000
2005
YEAR
Source: IAEA Energy and Economic Data Bank

Figure 4



Source: IAEA estimates except as indicated

Figure 5



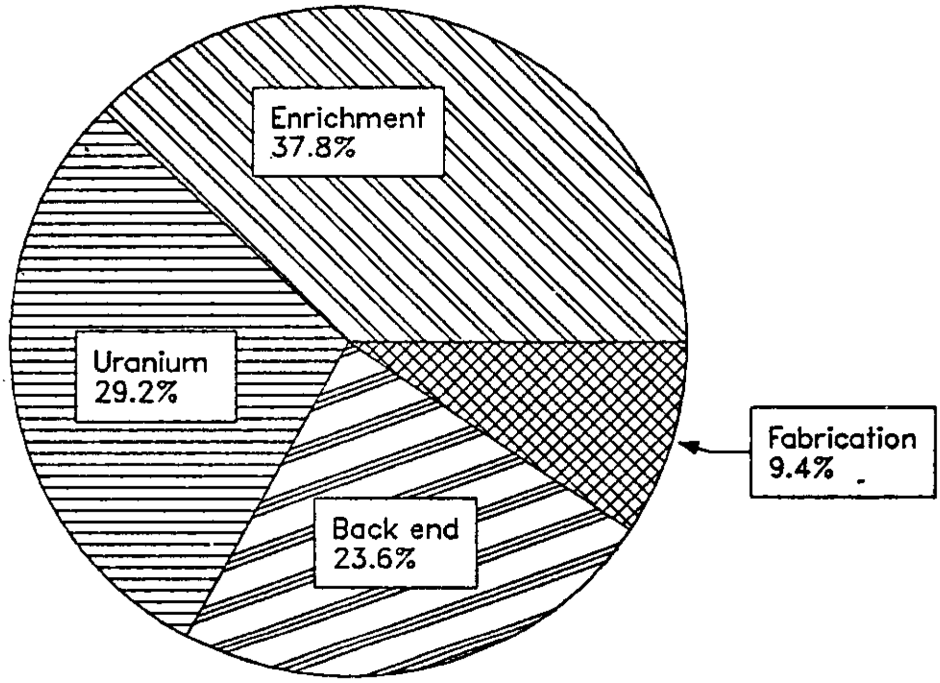
Source: "Nuclear and Fossil Power Plant Economics", Chaim Braun (EPRI), Paper presented at ANS Topical Meeting on Financial and Economic Bases for Nuclear Power, Washington (DC), USA, 8-11 April 1984.

Figure 6

IAEA-NENP-84-026

DISTRIBUTION OF LWR FUEL CYCLE COSTS

9.00 mills US $/KWh(e)



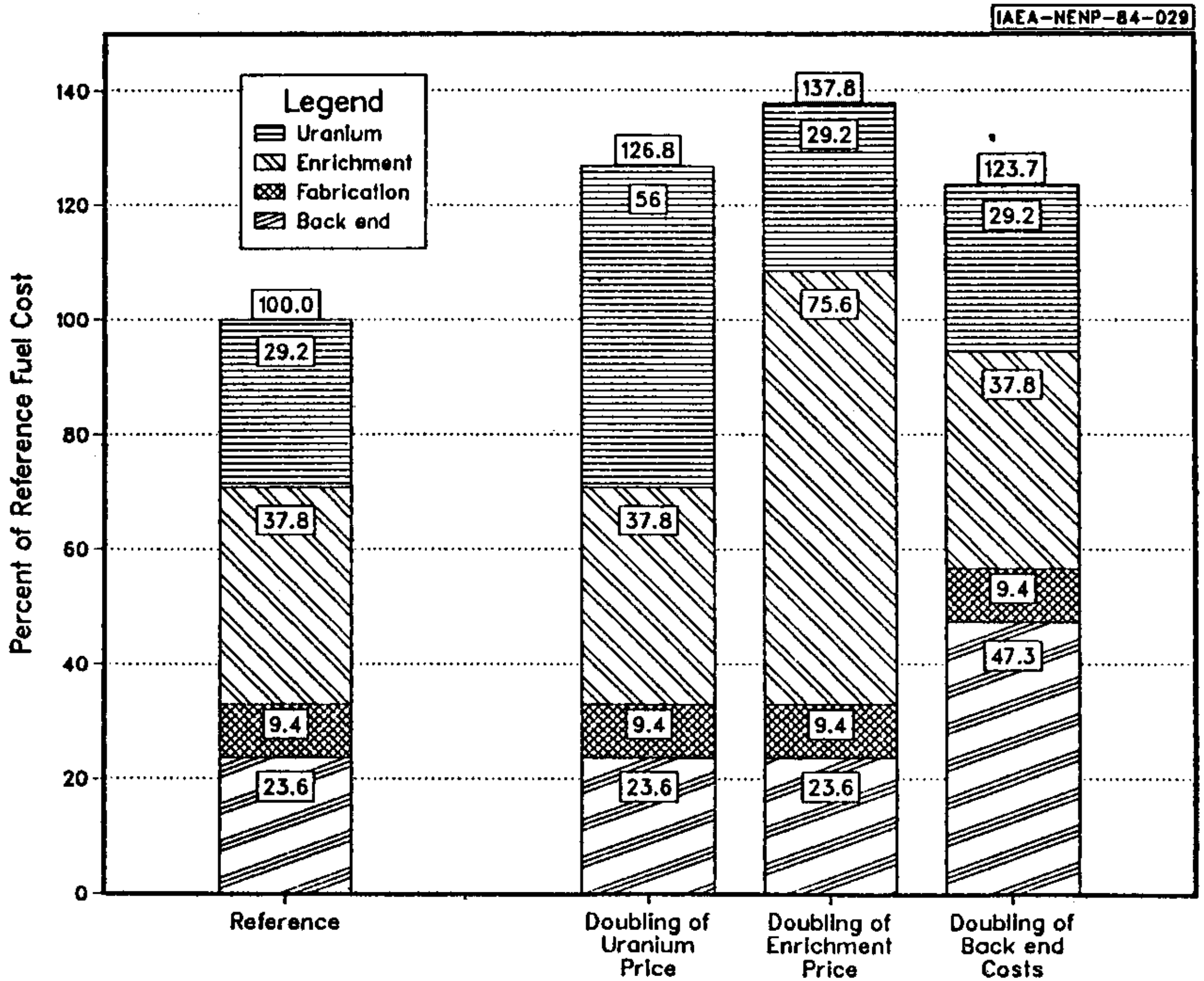
Notes:

- Figures for Uranium cost include conversion to UF_6
- Figures for Uranium and Enrichment costs are net, including the respective credits from reprocessing
- Figures for Fabrication include shipping of fresh fuel

084-350

Figure 7

Sensitivity of LWR Fuel Cycle Costs to Various Cost Parameters



Notes:

- Figures for Uranium cost include conversion to UF_6
- Figures for Uranium and Enrichment costs are net, including the respective credits from reprocessing
- Figures for Fabrication include shipping of fresh fuel