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MARKET SURVEY FOR NUCLEAR POWER

Memorandum by the Director General

1. In its annual report for 1972-73 the Board of Governors has briefly summarized for the benefit of the General Conference the steps to study the needs for nuclear power in developing countries[1] which have been taken as a sequel to the adoption by the Conference in 1971 of Resolution GC(XV)/RES/285 on the introduction, use and financing of nuclear power in developing countries.

2. In the following month a Working Group on Nuclear Power Plants of Interest to Developing Countries reviewed the status of the potential use of nuclear power plants in these countries and advised the Director General that it was desirable to carry out a detailed market survey. Such a survey was duly undertaken in 14 countries and was finished early this year. The resulting documentation consists of a separate report in respect of each country surveyed, a general report to which summaries of all the country reports and 15 technical appendices are attached, and a summary report which is reproduced in the Annex to this document.

3. It will be evident that neither the authorities of the countries surveyed nor nuclear industry have as yet had the necessary time to make a detailed study of all the information that the survey has produced. It can, however, already be forecast with some confidence that during the early years of the decade 1980-1989, which constitutes the study period, the number of nuclear power plants introduced into the grids of the countries surveyed will be relatively small. Nuclear generating capacity is likely to be used more intensively from 1983 or 1984 onwards.

4. As regards the unit sizes of plants, under the conditions assumed for the survey there will be no market in the 14 countries for reactors of less than 200 MW. The total market for larger sizes is likely to be:

Unit size (MW)	Total market (MW)
200 - 400	800 - 3000
600	24 600 - 27 600
800 - 1000	24 400 - 31 000

5. The importance of this forecast for the developing countries, the manufacturers of components of nuclear power plants and the organizations that may be called upon to finance

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[1] GC(XVII)/500, paras 96 and 97.

the installation of such plants seems to point to the desirability, in the light of the dates mentioned in paragraph 3 above, of surveying the situation anew around 1977-78. The purpose of such an exercise would be to confirm whether the present forecast was still valid and to identify the problems to which manufacturers of nuclear power plants and financing organizations should then devote most attention.

6. In the light of the situation with regard to the introduction of nuclear power into developing countries which the survey has thus revealed, the Director General suggests that the General Conference will wish to take note of the summary report annexed to this document and of his intention to bring the ideas summarized in the previous paragraph to the attention of the Board in 1976 when it is planning the Agency's activities for 1977 and subsequent years.

MARKET SURVEY FOR NUCLEAR POWER IN DEVELOPING COUNTRIES

Summary report

CONTENTS

Foreword

1. This summary report gives the results of a survey of the potential market for nuclear power plants in 14 developing countries, together with some background information and a description of the method of analysis adopted [1]. This survey was undertaken because many of the smaller, less-developed countries had expressed concern about the unavailability of small or medium-size nuclear power reactors suitable for application in their systems.

2. The purpose of the survey was to determine as precisely as possible the size and timing of the demand for nuclear power plants, including the required financing, in some developing countries where nuclear power might economically complement conventional energy sources. The power situation in the 14 developing countries concerned was analysed in detail. The survey covered the nuclear units to be commissioned in the decade 1980-89. It is to be noted that about six to eight years would elapse between the placing of an order and the date of commissioning.

3. Most of the data on which the analyses were based were provided directly by the countries concerned and were confirmed by visiting teams of experts. Other data were obtained by the survey staff and their consultants. A total of 26 experts qualified in various fields from eight countries and 11 Agency specialists took part in this work.

INTRODUCTION

Background information

4. It is generally recognized that within the coming decades nuclear power is likely to play an important role in many developing countries because, usually, such countries have limited indigenous energy resources and, in recent years, have been adversely affected by increases in world oil prices. The Agency has been fully aware of this potential need for nuclear power and has actively pursued a programme of assisting such countries with the development of their nuclear power programmes. So far, inter alia, the Agency has:

(a) Sponsored power reactor survey and siting missions;

(b) Conducted feasibility studies;

(c) Organized technical meetings;

(d) Published reports on small and medium power reactors; and

(e) Awarded fellowships for training in nuclear power and technology.

At present only eight developing countries[2] have nuclear power plants in operation or under construction, namely Argentina, Brazil, Bulgaria, the Czechoslovak Socialist Republic, India, Mexico, Pakistan and the Republic of Korea. The total of their nuclear power commitments to date is only about 5200 MW, as compared to an estimated installed electric generation capacity for these eight countries of about 56 000 MW in 1972. It is estimated that by 1980 only 8% of the installed electrical capacity of all developing countries will be nuclear. In contrast, in the industrialized countries, more than 16% of total electrical capacity is expected to be nuclear by 1980.

5. In view of the possible greater need for nuclear power in developing countries, it was recommended at the Fourth International Conference on the Peaceful Uses of Atomic Energy,

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[1] Copies of the General Report on the survey are available on request.

[2] As classified under the United Nations Development Programme.

held in Geneva in 1971, and at the fifteenth regular session of the General Conference in that year[3], that efforts should be intensified to assist these countries in their planning for nuclear power. In response to those recommendations, the Agency convened a Working Group on Nuclear Power Plants of Interest to Developing Countries which met from 11 to 15 October 1971 to review the status of the potential for nuclear power plants in these countries and advise on the desirability of carrying out a detailed market survey for such plants.

Objective and implementation

6. In response to the recommendation of the Working Group, the Director General decided that a survey should be undertaken. The major objectives of the survey as carried out were to determine the size and timing of the installation of nuclear power plants that, for economic reasons, could justifiably be built in each country during the decade 1980-1989, which is the period to which this study relates, and to determine the sensitivity of the results to certain key parameters. In November 1971 letters were sent to 23 developing countries considered to be the most promising candidates for the introduction of nuclear power in this study period. Fourteen of these countries expressed an interest in participating in the survey and agreed to make available relevant basic data and provide counterpart staff to work with the visiting teams of experts. Seven survey missions were undertaken as shown in the Appendix to this report. Details of the financial and manpower support for the survey are also given in the Appendix.

7. The information gathered by each mission was analysed by the survey staff, reviewed by the country concerned and served as the basis for the final analyses. These analyses included an evaluation of the operating conditions of each power system following an unplanned outage of one or more generating units, an analysis of alternative power system expansion plans involving hydro, nuclear and conventional thermal plants and an estimate of the present worth[4] of all costs for each case. The results served as a basis for the selection of near-optimum power system expansion programmes for each of the 14 countries concerned. From these expansion programmes, the number, size and timing of nuclear power units required were determined. The financing required for the thermal plant expansion programmes was also estimated.

8. The data and information gathered are not in such great detail as to allow the findings to be considered the equivalent of the results of rigorously determined feasibility studies of any specific installation; however, they are believed to be adequate for meeting the stated objectives of the survey.

PROJECTED NUCLEAR POWER MARKETS

The market for nuclear plants under reference conditions[5]

9. The projected markets for nuclear plants which will be commissioned in each participating country during the study period are shown in Table 1, based on the reference economic parameters. Also shown in the table are the percentage shares of each total thermal market which might be met by nuclear plants. It is seen that during the early years of the study period, the percentage of the total thermal capacity additions served by nuclear plants is relatively small; however, from 1983 onwards the nuclear portion is more than 70%. The hydro capacity additions are not included in these figures because these were generally based on each country's own plans and were assumed to remain constant for all expansion schedules considered.

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[3] See General Conference Resolution GC(XV)/RES/285.

[4] Present worth is discussed in paragraph 22 and defined in Appendix A of the General Report.

[5] For an explanation of reference conditions, see para. 21 and Table 10.

10. One of the specific objectives of the market survey was to investigate the potential demand for small reactor power plants. An initial study of the reactor manufacturing industry indicated that there was substantially no interest in sizes below 400-600 MW and no acceptable price data on sizes below these levels. Nevertheless, a decision was taken to establish at 100 MW the minimum size nuclear plant to be used in the evaluation studies. Costs were then established for sizes of 100, 200, 300 and 400 MW. However, the studies indicated that the 100-MW size was not economically justifiable in any of the countries under the conditions assumed; the smallest size was 200 MW and only a very few units in this size might be required. The first size for which any appreciable demand was indicated was 300 MW.

The distribution of market by sizes of units

11. Table 2 shows the market for small (200-400 MW) nuclear plants under reference conditions and under conditions which tend to favour conventional plants and nuclear plants respectively. As seen in this table, the market for small nuclear plants is very sensitive to oil-price escalation. With 0% escalation on oil prices, the potential market drops to zero from the reference case range of 3200-3500 MW. At 4% oil price escalation rate (or use of ORCOST-1 capital costs which give essentially the same result) the market for small nuclear plants increases to the range of 6500-7800 MW.

12. Table 3 shows how the market for medium size (600 MW) nuclear plants would be affected by changes in these same parameters. Here it is seen that the market under reference conditions of 24 600-27 600 MW drops to the minimum market level of 10 200-10 800 MW with 0% escalation on oil prices. The maximum nuclear market was encountered with a 6% discount rate or 2% escalation on oil prices. In this case, the potential market was increased to the range of 24 600-31 200 MW.

13. Table 4 shows the potential market for large (800-1000 MW) nuclear plants. In contrast to the situation pertaining to small nuclear plants, the market for large plants is relatively insensitive to changes in the economic parameters applied. The reason for this is that when systems become large enough to accept units in this size range, nuclear plants capture essentially all of the market even under conditions which tend to favour conventional plants. Thus, changing these conditions to make them more favourable to nuclear plants does not increase the market for such plants.

Summary of sensitivity studies

14. The influence of changes in the basic parameters, such as discount rate and oil-price escalation rate, on the potential market for nuclear plants is summarized in Table 5. Studies were also carried out for several countries to evaluate the effect of varying other parameters such as shadow exchange rate, nuclear fuel price escalation and method of depreciation of capital investment. It was found that penalizing foreign exchange costs by using a shadow exchange rate of 1.1 to 1.3 had essentially no effect on the nuclear market. This was because the higher foreign investment costs in the case of nuclear plants were balanced by the effective higher costs of imported oil for the oil-fired plants. The use of sinking fund rather than linear depreciation was found to increase the nuclear market by about 4%, whereas application of a 2%/yr escalation rate on nuclear fuel prices would have lowered the market by about 8%.

FINANCING

Calculation of annual cash flows

15. In order to determine the year-by-year domestic and foreign investment requirements for the expansion programmes under reference conditions, the annual domestic and foreign expenditures associated with each plant were calculated by means of a special computer programme. Plants were assumed to become operational on 1 January each year and their capital cost expenditures were assumed to reach 100% by the end of the preceding year.

16. Financing requirements for the total thermal plant expansion programmes are indicated in Table 6. The figures given include only the investment costs associated with the thermal plants added during the study period, plus the nuclear fuel cycle working capital. It is seen in this table that total investment costs range from US $306 million in the case of Jamaica to US $5849 million for Mexico. More details of the financing requirements are given in Section 9 of the General Report.

17. Table 7 gives the total financing requirements by years for the 14 countries concerned. It is seen in this table that with the low load forecast, domestic financing requirements will reach a peak of US $1046 million and foreign financing requirements US $1670 million in 1984. For the high forecast, the corresponding peaks are US $1232 million and US $2118 million respectively, also in 1984. As mentioned above, costs refer only to those plants commissioned during the period 1980-1989.

18. The financing requirements for the nuclear fuel cycle are shown separately in Tables 6 and 7, because the arrangements for meeting these costs may differ from those for the plant construction. The investment associated with the nuclear fuel amounts to US $1341 million for the low forecast and US $1589 million for the high forecast. Essentially all of the nuclear fuel investment costs will be foreign.

BASES OF ANALYSES

19. Table 8 shows the present and projected population and gross national product (GNP), along with corresponding growth rates and the GNP/capita growth rates, for each of the countries studied. These data were used as a basis for the market survey load forecasts. In cases where GNP data were for years other than given in Table 8, such data were converted to US dollars at the 1 January 1973 value, using a general inflation rate of 4%/yr.

20. Forecasts of energy, demand and load factor were made for each participating country. These are summarized in Table 9. Details of how these forecasts were carried out are given in Appendix F to the General Report. For several countries both a low and a high forecast were studied. In the market survey forecast a world-wide generalized correlation of electricity consumption per capita and GNP per capita was used. It was assumed that each country's future electricity consumption would follow a characteristic path which depends on the historical relationship between these two factors. The country forecasts were accepted as provided by the countries themselves, although they appeared to have been prepared by means of various methods.

21. External costs were not taken into account, nor were taxes and restraints on foreign capital. Definitions of the costs and other economic parameters are given in Appendix D to the General Report. The values of the economic parameters selected for the reference conditions and for the sensitivity studies are reproduced in Table 10. In the sensitivity studies, the reference condition parameters were kept constant except for the single parameter being studied.

22. Alternative generating system expansion configurations, involving nuclear and conventional thermal units were envisaged to meet the required thermal capacity additions (see Table 11) and the present worth of costs associated with each configuration determined by means of a computer programme and used as a basis for selecting the near-optimum configuration. The capital and operating costs of each expansion alternative plan for the period 1980-2000 were estimated by means of this programme, called the Wien Automatic System Planning Package (WASP). The two-decade period was used in the evaluation in order to minimize the effect of not operating plants built during the study period to the end of their economic life-time, even though the study was specifically concerned only with the first decade of this period. Each plant was credited with a salvage value at the end of the year 2000. All costs were discounted to 1 January 1973 to determine their present worth. The method of treating escalation of capital costs and fuel costs is given in Appendix D to

the General Report. By varying the combination of nuclear and conventional plants added during the study period, it was possible to determine, in each case, that combination of plants which is referred to as the "near-optimum" expansion plan.

23. Since it is not clear whether environmental considerations will play an important role in the participating countries or not, no allowance was made for these in estimating the costs in these studies, except that capital costs for fossil-fuelled plants include electrostatic precipitators to remove particulate matter from the stack gases. If future environmental considerations require the use of low sulphur fuels or equipment to alleviate deleterious effects such as thermal or gaseous discharges, capital and/or operating costs will increase and thereby influence the competition between fossil and nuclear plants. It is at present considered that if the full complement of environmental control equipment were added to both nuclear and conventional plants the costs of fossil-fired plants would be increased substantially more than those of nuclear plants. This factor was not examined in detail in these studies; however, a qualitative and approximate quantitative discussion is to be found in Appendix B to the General Report.

CHARACTERISTICS OF POWER SYSTEMS EVALUATED

System capacities at start of study period

24. The system assumed to be in existence at the start of the study period in each country included:

(a) All of the generating units actually existing and those firmly committed (which, generally, were sufficient to meet peak load demands up to 1975-77); and

(b) Generating units of the same type as included in (a) in the sizes and on such schedules as to meet the forecasted system demand and provide adequate reserve margins at the end of 1979.

The resulting capacities in each country are shown in Table 11.

Capacity additions during study period

25. The capacity additions required each year to provide adequate reserve margins over the forecasted peak demands were determined by using the WASP programme. The criterion for adequate reserve margin was that the average annual loss-of-load probability[6] should be about 0.005. Having established the required total capacity additions, the capacity available from the installed hydro and pumped storage plants was subtracted to determine required net thermal capacity additions (see Table 10). Such additions represent the total "market" for new capacity to be shared by nuclear and conventional plants.

26. In regard to hydro and pumped storage additions, these were assumed to follow each country's existing plans, or an extension of these, except in a few special cases. In any event, once a schedule for hydro and pumped storage units was established, it was held constant throughout all of the cases studied and, therefore, did not directly affect the comparative economic evaluation of nuclear versus conventional thermal units.

27. Table 11 summarizes the installed capacities for each country in 1979, the capacity additions made from 1980 to 1989 and the resulting total capacities in 1989, the end of the study period.

Capacity additions following study period

28. A single expansion plan for the 1990-2000 period was drawn up to meet the forecasted load growths for each country (see paragraph 22). These expansion schedules were selected

[6] Loss-of-load probability is defined in Appendix A to the General Report.

to provide essentially the same loss-of-load probability as that achieved during the study period and were attached to each alternative plan being evaluated. In the second decade schedules, hydro capacity additions were generally based on the country's own plans and the required thermal capacity additions were divided roughly equally between nuclear and conventional plants.

Characteristics of generating units considered as expansion alternatives

(a) Capital costs

29. These costs were determined by the ORCOST computer programme. ORCOST-1 costs are based on mid-1971 plant costs in the United States of America updated to 1 January 1973 by escalating equipment and materials costs at 5%/yr and construction labour costs at 15%/yr. They show a ratio of pressurized water reactors to oil-fired plants of 1.4 to 1.8 depending on the country and the rating, in megawatts. ORCOST-3 costs include added costs reflecting recent sharp increases in nuclear plant construction costs in the United States of America up to 1 January 1973, with very minor changes in fossil-fired plant costs. They show a ratio of pressurized water reactors to oil-fired plant costs of 1.7 to 2.2 depending on the country and the rating in megawatts (see Appendix B to the General Report for details). In general, the costs of gas-fired plants were about 10% below the costs of the oil-fired units, while the costs of coal- and lignite-fired plants were 12% and 23% above the oil-fired plant costs, respectively.

(b) Fuel costs

30. Unescalated prices for imported fuel oil delivered to the plant sites ranged from 130-200 US¢/10^6 kcal. Nuclear fuel costs were of the order of 50-60 US¢/10^6 kcal. Costs of indigenous fuels such as coal and lignite were based on information supplied by each country.

(c) Other data

31. Other data required for the evaluation included minimum operating load levels of each plant (in MW), base load and incremental heat rates (in kcal/kWh), forced outage rates (in %/year), scheduled maintenance days per year and operating and maintenance costs (in $/kW x month). Except in special cases, these data were standardized for all of the evaluations as described in Appendices E, G, I and J to the General Report.

APPENDIX

SURVEY MISSIONS

Turkey-Greece	3-21 July 1972
Argentina-Mexico	7 August-1 September 1972
Jamaica-Chile	4-15 September 1972
Republic of Korea-Singapore-Philippines	23 October-17 November 1972
Pakistan-Arab Republic of Egypt	13 November-1 December 1972
Thailand-Bangladesh	20 November-8 December 1972
Yugoslavia	4-5 and 15-17 January 1973

FINANCIAL AND MANPOWER SUPPORT

Situation in April 1973

1. Since the market survey was not foreseen at the time the Agency's budget for 1972 was prepared, financial support was sought and obtained from the following countries and financial institutions:

Germany, Federal Republic of		US $ 25 000
Inter-American Development Bank		25 000
International Bank for Reconstruction and Development		50 000
United States - Agency for International Development		25 000
Atomic Energy Commission		9 950
Export-Import Bank		75 000
	TOTAL	US $209 950

2. In addition, several countries have provided experts on either a cost-free or partially cost-free basis in the amounts shown:

	Approximate man-weeks
Canada	22
France	4
Germany, Federal Republic of	48
India	3
Japan	17
Sweden	9
United Kingdom of Great Britain and Northern Ireland	14
United States of America	19
TOTAL	136

3. The 14 participating countries have contributed counterpart personnel and have borne the expenses of each survey mission during the time it spent in the country, in addition to defraying the cost of preparing responses to requests for information and the data required for the analyses.

4. The Agency's contribution has included US $20 000 in cash and about 260 man-weeks of Professional services together with secretarial and administrative support equivalent in value to some US $112 000.

5. It is thus estimated that the total cost of the survey has amounted to US $555 000, a figure which includes an amount of more than US $100 000 for cost-free services provided by its sponsors.

Table 1
Projected annual nuclear plant additions by country[a/] [b/] in megawatts

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total nuclear additions (MW)	Total thermal market (MW)	Nuclear percentage of total market
Argentina[c/]	600			600	2x600		800	800	1000	1000	6000	6800	88.2
Bangladesh-L												1300	0
Bangladesh-H										600	600	3850	15.6
Chile					300	300	300			300	1200	1750	68.6
Egypt, Arab Republic of				600		600	600	600	2x600	600	4200	4800	87.5
Greece			400	400	400	600	600	600	600	600	4200	4500	93.3
Jamaica-L												1000	0
Jamaica-H										300	300	1550	19.3
Korea, Republic of		600	600	600	2x600	600	2x600	2x600	600+800	600+800	8800	9100	96.7
Mexico		600	600	600+800	800	3x800	3x800	1000	2x800 1000	3x1000	14800	19600	75.6
Pakistan							600				600	2000	30.0
Philippines			600		600		800	800		1000	3800	5400	70.3
Singapore-L												2100	0
Singapore-H							600	600	600	800	2600	4700	55.3
Thailand					400	400	600		600	600	2600	3850	67.5
Turkey-L									600	600	1200	3000	40.0
Turkey-H							600	600	600+800	600	3200	4850	66.0
Yugoslavia-L				600	600	800		800	1000	1000	4800	6000	80.0
Yugoslavia-H			600	800	800	800	2x800	2x800	1000	2x1000	9200	10600	86.8
Total nuclear low load	600	1200	2200	4200	5500	5700	7900	5800	9000	10100	52200	71200	73.3
Total nuclear high load	600	1200	2800	4400	5700	5700	10700	7800	10400	12800	62100	83350	74.5
Nuclear as % of total thermal (L)	13.5	26.4	44.0	73.7	75.3	86.4	86.3	78.4	87.3	94.8			
Nuclear as % of total thermal (H)	12.5	24.0	51.9	70.4	68.3	83.2	89.9	83.0	88.9	98.5			

a/ Under reference conditions.

b/ L denotes market based on low load forecast. H denotes market based on high load forecast.

c/ Market for countries with one load forecast were included in both low and high load totals.

Table 2

Potential market for small (200-400 MW) nuclear plants, in megawatts

Year of commissioning	Market under reference conditions[a]		Minimum nuclear market conditions[b]		Maximum nuclear market conditions[c]	
	Low forecast	High forecast	Low forecast	High forecast	Low forecast	High forecast
1980	-	-	No nuclear market	No nuclear market	2 x 300	3 x 300
1981	-	-			300	300
1982	400	400			300, 400	300, 400
1983	400	400			300, 400	2 x 400
1984	300, 2 x 400	300, 2 x 400			2 x 300, 2 x 400	300, 3 x 400
1985	300, 400	300, 400			300, 400	300, 2 x 400
1986	300	300			300	2 x 300
1987	-	-			200, 400	200, 400
1988	-	-			200, 400	200, 2 x 400
1989	300	2 x 300			2 x 300	2 x 300
Total	3 200	3 500	0	0	6 500	7 800

a/ 8% discount rate, 2% escalation on oil prices.

b/ 8% discount rate, 0% escalation on oil prices.

c/ 8% discount rate, 4% escalation on oil prices.

Table 3

Potential market for medium (600 MW) nuclear plants, in megawatts

Year of commissioning	Market under reference conditions[a]		Minimum nuclear market conditions[b]		Maximum nuclear market conditions[c]	
	Low forecast	High forecast	Low forecast	High forecast	Low forecast	High forecast
1980	600	600	-	-	2 x 600	3 x 600
1981	2 x 600	2 x 600	2 x 600	2 x 600	2 x 600	3 x 600
1982	3 x 600	4 x 600	2 x 600	3 x 600	4 x 600	5 x 600
1983	6 x 600	4 x 600	3 x 600	600	6 x 600	4 x 600
1984	6 x 600	5 x 600	2 x 600	600	7 x 600	6 x 600
1985	3 x 600	3 x 600	2 x 600	2 x 600	3 x 600	4 x 600
1986	6 x 600	8 x 600	2 x 600	2 x 600	6 x 600	7 x 600
1987	4 x 600	6 x 600	2 x 600	2 x 600	4 x 600	6 x 600
1988	5 x 600	7 x 600	600	2 x 600	5 x 600	8 x 600
1989	5 x 600	6 x 600	2 x 600	2 x 600	5 x 600	6 x 600
Total	24 600	27 600	10 800	10 200	26 400	31 200

a/ 8% discount rate, 2% escalation on oil prices.

b/ 8% discount rate, 0% escalation on oil prices.

c/ 8% discount rate, 4% escalation on oil prices.

Table 4

Potential market for large (800-1000 MW) nuclear plants, in megawatts

Year of commissioning	Market under reference conditions[a]		Minimum nuclear market conditions[b]		Maximum nuclear market conditions[c]	
	Low forecast	High forecast	Low forecast	High forecast	Low forecast	High forecast
1980	-	-	-	-	-	-
1981	-	-	-	-	-	-
1982	-	-	-	-	-	-
1983	800	2 x 800	800	2 x 800	800	2 x 800
1984	800	2 x 800	800	2 x 800	800	2 x 800
1985	4 x 800	4 x 800	4 x 800	4 x 800	4 x 800	4 x 800
1986	5 x 800	9 x 800	5 x 800	7 x 800	5 x 800	9 x 800
1987	3 x 800 1000	4 x 800 1000	2 x 800 1000	3 x 800 1000	3 x 800 1000	4 x 800 1000
1988	3 x 800 3 x 1000	4 x 800 3 x 1000	3 x 800 3 x 1000	4 x 800 3 x 1000	3 x 800 3 x 1000	4 x 800 3 x 1000
1989	800 6 x 1000	2 x 800 7 x 1000	800 6 x 1000	800 7 x 1000	800 6 x 1000	2 x 800 7 x 1000
Total	24 400	31 000	23 600	29 400	24 400	31 000

a/ 8% discount rate, 2% escalation on oil prices.

b/ 8% discount rate, 0% escalation on oil prices.

c/ 6 & 10% discount rates, 2 & 4% escalation on oil prices (all combinations).

Table 5

Influence of changes in economic parameters on the nuclear power market, in megawatts

Plant size	Market under reference conditions[a]		Minimum nuclear market conditions[b]		Maximum nuclear market conditions[c]	
	Low forecast	High forecast	Low forecast	High forecast	Low forecast	High forecast
Small (200-400 MW)	3 200	3 500	0	0	6 500	7 800
Medium (600 MW)	24 600	27 600	10 800	10 200	26 400	31 200
Large (800-1000 MW)	24 400	31 000	23 600	29 400	24 400	31 000
Total	52 200	62 100	34 400	39 600	57 300	70 000

a/ 8% discount rate, 2% escalation on oil prices.

b/ 8% discount rate, 0% escalation on oil prices.

c/ 8% discount rate, 4% escalation on oil prices (essentially the same market was obtained with 6% discount rate or ORCOST-1 capital costs).

Table 6

Financing requirements by country for all thermal plants[a/] (US $ x 10^6)[b/]

Country	Plant investment		Nuclear fuel cycle investment	Total
	Domestic	Foreign		
Argentina	1 068	1 047	144	2 259
Bangladesh-L	76	320	0	396
Bangladesh-H	187	919	17	1 123
Chile	191	548	41	780
Egypt, Arab Republic of	378	1 133	117	1 628
Greece	501	1 141	122	1 764
Jamaica-L	44	262	0	306
Jamaica-H	77	443	10	530
Korea, Republic of	1 222	1 818	239	3 279
Mexico	2 859	2 642	348	5 849
Pakistan	125	421	17	563
Philippines	370	1 032	92	1 494
Singapore-L	121	295	0	416
Singapore-H	289	946	69	1 304
Thailand	341	802	76	1 219
Turkey-L	302	762	34	1 098
Turkey-H	394	1 289	86	1 769
Yugoslavia-L	860	805	111	1 776
Yugoslavia-H	1 466	1 440	211	3 117
Total Low forecast (L)	8 458	13 028	1 341	22 827
Total High forecast (H)	9 468	15 621	1 589	26 678

a/ Under reference case conditions (see Table 10).

b/ Based on the value of the United States dollar on 1 January 1973.

Table 7

Annual and total financing requirements for nuclear and conventional plants commissioned during the study period (US $ x 10^6)a/

Year	Low load forecast				High load forecast			
	Plant investment		Nuclear fuel cycle investment	Total	Plant investment		Nuclear fuel cycle investment	Total
	Domestic	Foreign			Domestic	Foreign		
1975	8	9		17	8	9		17
1976	37	45		82	40	48		88
1977	155	203		358	169	214		383
1978	416	598	2	1 016	455	644	2	1 101
1979	637	902	19	1 557	693	980	19	1 692
1980	771	1 107	38	1 916	813	1 200	40	2 053
1981	870	1 295	69	2 234	922	1 449	84	2 455
1982	970	1 512	119	2 600	1 081	1 790	121	2 992
1983	1 025	1 629	153	2 807	1 183	1 998	155	3 336
1984	1 046	1 670	157	2 862	1 232	2 118	165	3 515
1985	1 036	1 628	196	2 860	1 194	2 084	267	3 545
1986	856	1 568	155	2 378	961	1 744	206	2 911
1987	501	838	222	1 451	568	1 077	259	1 904
1988	131	224	212	567	149	267	271	687
Total	8 458	13 028	1 341	22 827	9 468	15 621	1 589	26 678

a/ Based on the value of the United States dollar on 1 January 1973.

Table 8

Summary of population and GNP

Country	Population[a] (10^6)			Population growth rate[d] (%/yr)		GNP[b] (10^9 US $/yr)			GNP growth rate (%/yr)		GNP/capita growth rate[d] (%/yr)	
	1972	1980	1990	1972-80	1981-90	1972	1980	1990	1972-80	1981-90	1972-80	1981-90
Argentina	24.0	27.3	31.8	1.6	1.5	28.9	45.4	73.2	5.8	4.9	4.1	3.3
Bangladesh	72.1	88.6	114.5	2.6	2.6	3.8	6.1	11.0	6.1	6.1	3.4	3.4
Chile	10.2	11.9	14.5	2.0	2.0	6.7	10.0	16.4	5.1	5.1	3.0	3.0
Egypt, Arab Republic of	34.7	40.6	49.5	2.0	2.0	7.4	11.9	21.5	6.1	6.1	4.0	4.0
Greece	8.9	9.3	9.9	0.6	0.6	10.6	17.3	29.8	6.3	5.6	6.2	5.0
Jamaica	1.9	2.2	2.6	1.5	1.5	1.3	2.2	4.2	6.6	6.6	5.0	5.0
Korea, Republic of	32.3	36.5	42.3	1.5	1.5	10.0	19.0	37.7	8.4	7.1	6.8	5.5
Mexico	54.2	71.5	96.0	3.5	3.0	39.4	68.3	129.3	7.1	6.6	3.5	3.5
Pakistan	55.7	65.2	79.5	2.0	2.0	11.3	17.9	31.7	5.9	5.9	3.8	3.8
Philippines[c]	20.7	25.2	30.9	2.5	2.0	5.7	9.9	18.7	7.1	6.6	4.5	4.5
Singapore	2.1	2.4	2.8	1.7	1.6	2.7	5.6	9.8	9.6	5.7	7.8	4.0
Thailand	38.3	48.6	62.5	3.0	2.5	8.3	15.1	29.2	7.8	6.8	4.7	4.2
Turkey	37.3	45.4	58.2	2.5	2.5	16.4	27.3	48.5	6.6	5.9	4.0	3.3
Yugoslavia	20.8	22.5	24.9	1.0	1.0	16.5	27.1	49.0	6.4	6.1	5.3	5.0

a/ Population forecast used for Market Survey (L) load forecast.

b/ In 1 January 1973 United States dollars (based on the value of the United States dollar in 1964 at an inflation rate of 4%/yr).

c/ Luzon only.

d/ Average annual compound rates over periods shown.

Table 9

Forecasts of system load characteristics

Country	Energy generation MWh x 10^6		Energy generation growth rate 1980-1990 %/yr	System load factor (%) 1980-1990	Peak demand in MW	
	1980	1990			1980	1990
Argentina	42.0	84.2	7.2	58.3	8 230	16 500
Bangladesh-L	3.1	8.1	10.1	55.0	640	1 690
Bangladesh-H	4.8	21.7	16.3	55.0	1 000	4 500
Chile	11.4	23.7	7.6	60.5	2 150	4 470
Egypt, Arab Republic of	20.7	47.0	8.5	68.0	3 280	8 380
Greece	26.8	55.3	7.5	65.0	4 710	9 720
Jamaica-L	3.9	8.3	8.0	68.0	650	1 400
Jamaica-H	4.8	13.3	10.8	68.0	810	2 240
Korea, Republic of	31.2	76.7	9.4	66.0	5 360	13 200
Mexico	72.7	178.9	9.5	61.2	13 500	33 200
Pakistan	17.0	36.2	7.9	58.2	3 320	7 090
Philippines	14.8	35.2	9.0	65.0	2 610	6 190
Singapore-L	8.5	17.3	7.4	65.0	1 500	3 040
Singapore-H	9.1	27.8	11.8	68.0	1 520	4 650
Thailand	15.7	39.3	9.7	66.0	2 710	6 800
Turkey-L	23.4	51.3	8.2	63.7	4 200	9 200
Turkey-H	29.0	81.5	10.9	63.7	5 190	14 600
Yugoslavia-L	64.4	122.4	6.7	67.5	10 900	20 700
Yugoslavia-H	87.5	165.5	6.6	67.5	14 810	27 990

Table 10

Economic parameters used in the study

	Reference conditions		Sensitivity studies	
	Study values[a]	Approximate equivalent "real values"	Study values[a]	Approximate equivalent "real values"
Discount rate	8%	12%	6%, 10%	10%, 14%
Capital and O & M cost escalation	0%	4%	-	-
Fuel oil and gas price escalation rate	2%	6%	0%, 4%	4%, 8%
Coal price escalation rate	2%	6%	0%	4%
Nuclear fuel price escalation rate	0%	4%	2%[b]	6%
Capital cost of plants[c]	ORCOST-3		ORCOST-1	
Depreciation[d]	Linear		Sinking fund[b]	
Ratio of exchange rate used to official rate[e]	1.0		1.1-1.3[b]	

a/ The general inflation rate was assumed constant at 4%/yr.

b/ This value was used for sensitivity studies in only a few selected cases.

c/ See paragraph 29 for discussion of ORCOST cost model.

d/ Used as a basis of estimating plant salvage values.

e/ This is intended to show the effect of scarcity of foreign capital on capital-intensive projects. The devaluation of the United States dollar in March 1973 was not taken into account in this study.

Table 11

Summary of system expansion schedules[a/]

Country	System as of 1979				Additions 1980-1989				Thermal capacity retired	Systems as of 1989			
	Thermal		Hydro and pumped storage	Total	Thermal		Hydro and pumped storage	Total		Thermal		Hydro and pumped storage	Total
	Conventional	Nuclear			Conventional	Nuclear				Conventional	Nuclear		
Argentina	5 997	919	3 026	9 942	800	6 000	4 160	10 960	1 016	5 781	6 919	7 186	19 886
Bangladesh-L	654	-	130	784	1 300	-	-	1 300	-	1 954	-	130	2 084
Bangladesh-H	904	-	130	1 034	3 250	600	-	3 850	49	4 105	600	130	4 835
Chile	934	-	1 612	2 546	550	1 200	720	2 470	-	1 484	1 200	2 332	5 016
Egypt, Arab Republic of	2 149	-	1 310[b/]	3 459	600	4 200	420	5 220	181	2 568	4 200	1 730	8 498
Greece	4 061	-	1 560	5 621	300	4 200	2 565	7 065	296	4 065	4 125	4 200	12 390
Jamaica-L	787	-	15	802	1 000	-	-	1 000	-	1 787	-	15	1 802
Jamaica-H	937	-	15	952	1 250	300	-	1 550	-	2 187	300	15	2 502
Korea, Republic of	4 705	1 195	710	6 610	300	8 800	-	9 100	-	5 005	9 995	710	15 710
Mexico	8 341	670	6 200	15 211	4 800	14 800	2 200	21 800	490	12 651	15 470	8 400	36 521
Pakistan[c/]	2 428	125	839	3 392	1 400	600	1 471	3 471	-	3 828	725	2 310	6 863
Philippines	2 799	-	569	3 368	1 600	3 800	-	5 400	165	4 234	3 800	569	8 603
Singapore-L	1 819	-	-	1 819	2 100	-	-	2 100	150	3 769	-	-	3 769
Singapore-H	1 841	-	-	1 841	2 100	2 600	-	4 700	175	3 766	2 600	-	6 366
Thailand	2 348	-	1 341	3 689	1 250	2 600	900	4 750	-	3 598	2 241	2 600	8 439
Turkey-L	2 200	-	2 490	4 690	1 800	1 200	4 019	7 019	60	4 080	1 200	6 369	11 649
Turkey-H	2 950	-	3 128	6 178	1 650	3 200	5 981	10 831	60	4 680	3 200	9 069	16 949
Yugoslavia-L	5 220	640	6 703	12 563	1 200	4 800	4 750	10 750	-	6 420	5 440	11 453	23 313
Yugoslavia-H	7 720	640	7 678	16 038	1 400	9 200	4 275	14 875	-	9 120	9 840	11 953	30 913
Total low forecast (L)	44 442	3 549	26 505	74 496	19 000	52 200	21 205	92 405	2 358	61 224	55 749	47 570	164 543
Total high forecast (H)	48 114	3 549	28 218	79 881	21 250	62 100	22 692	106 042	2 432	67 072	65 649	50 770	183 491

a/ Reference conditions.

b/ Excludes 1135 MW emergency hydro.

c/ In critical quarter.