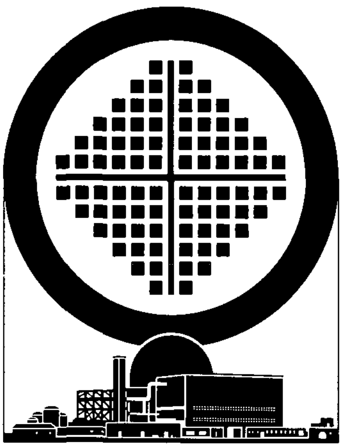
Expansion Decision Timing

The USAEC has recently estimated that the time from process decision date to equivalent full production date is approximately seven years for either gaseous diffusion or centrifuge plants, the latter having a somewhat shorter construction time but a longer start-up time. The URENCO requirement of only four years advance commitment in supply contracts implies that they estimate only about four years lead time for planning capacity expansion.

It should be observed that since gaseous diffusion plants require large increments of electricity generation, their lead time cannot be less than that required to build the associated electric power plants. Centrifuge plants, having much smaller power requirements, are not necessarily subject to this limitation.

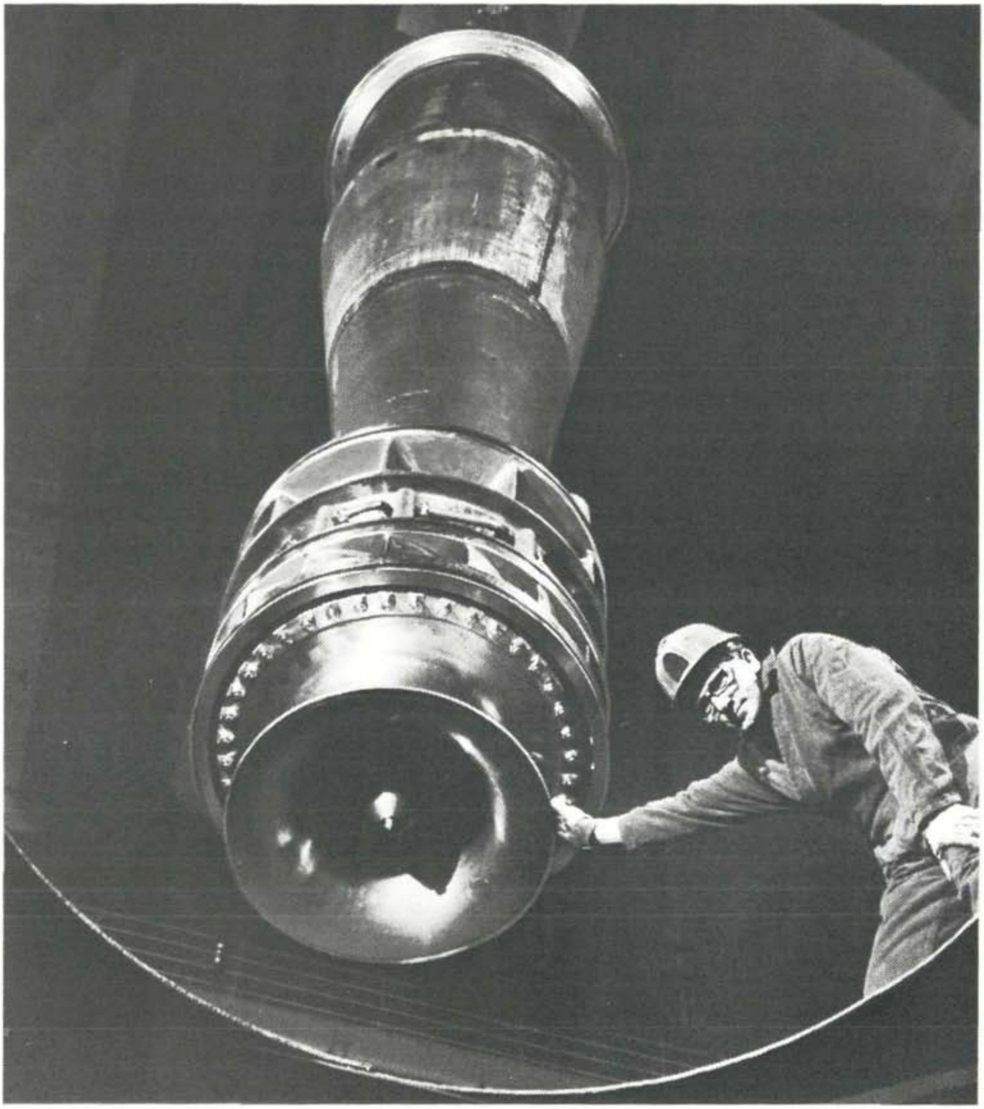


The Need for Fast Breeder Reactors

by R. Skjoeldebrand

The preceding articles in this issue have shown that the world for many decades to come will have to rely to an ever increasing extent on nuclear energy to meet the demands for primary energy. To meet these requirements we must, however, have a reactor type with lower needs for uranium and also enrichment services, which otherwise may place a limitation on how far nuclear energy can be used. The breeder reactor, with its ability to convert uranium 238 into fissile plutonium, is a solution and would indeed offer a practically inexhaustible source of energy from uranium for centuries to come. The basic reason is that the very much higher utilization of the uranium in a breeder reactor (more than 60 times higher than in a light water reactor) permits the use of uranium of much higher initial price, and the available reserves multiply as a consequence.

Several countries have over many years devoted a considerable part of the nuclear energy programmes to breeder development and the first six medium-sized demonstration plants are now either already in the early stages of operation or under construction. All are of the same basic type, i.e. the liquid metal cooled fast breeder, although the alternatives, e.g. a gas cooled breeder, would have been possible and could have offered some advantages. These programmes are extremely costly and it has been estimated that development of a first commercial prototype will require a total cost of at least $2000 - $3000 million; each programme occupies several thousand scientists in government laboratories and in industry.



The primary pump being lowered into position in the prototype 250 MW(E) fast reactor whose construction has just been completed at Dounreay, Caithness, Scotland . . . UK Atomic Energy Authority.

Experience of the early experimental fast liquid metal cooled reactors has generally been positive and it seems that the technology can be mastered, but some components, e.g., steam generators with liquid sodium on the primary side have given considerable problems of reliability. The safety of the fast breeder, although the problems are partly different from those of the present thermal reactors, also appears to be manageable, but further research and development work will be needed to assure all possible solutions. It is, however, unlikely that the major long-term safety problems of the fast breeder will be associated with the reactors themselves, but rather with the handling of the extremely poisonous plutonium in the different parts of the fuel cycle. Each breeder reactor will contain an inventory of several tons of plutonium and will produce about 1/10 of the inventory in new plutonium fuel each year. This has to be transported from the reactor, reprocessed and refabricated into new fuel, and these operations may well have inherently greater risks than the reactors, although experience again would indicate that they also are reasonable and manageable. The most logical solution to minimize the risks for the future may be the planning of large energy parks with generating capacities of more than 50 - 100 GWe each, and self-supplying for all fuel cycle operations.

At the present time even the most optimistic forecasts see an industrial introduction of the breeder reactor only in the mid 1980's. The power industry is capital intensive and the plants have a long lifetime of at least 25 - 30 years. In addition, a new reactor type cannot immediately supplant the older types for all new orders, as the manufacturing industry must be allowed time for tooling up and orderly transition to the new type. Furthermore, the rate of installation of breeders may become limited by the availability of plutonium for its fuel cycle. It will thus take a considerable additional time before the breeder reactors will play any major role in the total generation of electric power. The recent NEA/IAEA study of uranium resources, production and demand (1) foresees that fast breeders may account for 4% - 10% of the total installed nuclear capacity in 1980, and a US study (2) forecasts that breeders may be about 30% of the installed nuclear generation in 2000. This means that the demands for uranium and enrichment services still will be dominated by the other types of reactors even at that time, and that they will continue to increase even though the annual rate of increase will begin to slacken. It is only one or two decades later that a real decrease in the demand for uranium and enrichment can be foreseen, when the breeders would dominate the market.

The need for the breeder must be seen in a long-term perspective, as it is in the long term that it can really make nuclear fission energy into a major alternative to other energy sources. It is still the only real alternative that we can now see. While the first demonstration breeders are now a reality, we will have to wait at least another 10 - 15 years for a practical demonstration of a fusion reactor which would correspond to the first breeder experiment (EBR-1) in 1951. Solar and geothermal plants, which could also provide inexhaustible energy sources, are still farther away, and their practical feasibility not at all proven.

The plutonium breeder will also offer the obvious solution for the use of what are at present by-products from nuclear power production, viz. depleted uranium from the enrichment plants and plutonium produced by the present types of thermal reactors. Without use in breeders we would in 2000 have some 5 million tons of depleted uranium and about 6000 tons of plutonium in store. The latter could be recycled to some extent in thermal reactors instead of using fresh enriched uranium, but using it in breeders would be much more efficient and thus much more valuable. The conclusion must thus be that the breeder reactor will be needed, and its industrial realization is one of our urgent tasks for the next decade.

References:

1) OECD/NEA-IAEA. Report on Uranium Resources, Production and Demand, 1973.

2) Nuclear Power 1973 - 2000, WASH-1139 (72), December 1972.

3) H. Schmale: Probleme des Brennstoffkreislaufes Schneller Brüter, Atomwirtschaft, August - September 1973.

A Survey of Nuclear Power in Developing Countries

by O.B. Falls, Jr.

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. Consequently, many of the smaller, less-developed countries have expressed concern about the unavailability of nuclear power reactors of a suitable size for application in their system.

At present only eight developing countries[1] have nuclear power plants in operation or under construction – Argentina, Brazil, Bulgaria, the Czechoslovak Socialist Republic, India, the Republic of Korea, Mexico and Pakistan. The total of their nuclear power commitments to date is only about 5200 MW, as compared to an estimated 1972 installed electric generation capacity for these eight countries of about 56000 MW. It is estimated that by 1980 only 8% of the installed electrical capacity of all developing countries of the world will be nuclear. In contrast, in the industrialized countries more than 16% of total electrical capacity will be nuclear by 1980.

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 programmes. Consequently, in view of the indicated need for nuclear power in developing countries, it was recommended at the Fourth International Conference on the Peaceful Uses of Atomic Energy, held in Geneva in 1971, and at the fifteenth regular session of the IAEA's General Conference, that efforts should be intensified to assist these countries in planning for nuclear power. In response to those recommendations the Agency convened a Working Group on Nuclear Power Plants of Interest to Developing Countries in October 1971 to review the then current status of the potential for nuclear power plants in these countries, and to advise on the desirability of carrying out a detailed market survey for such plants.

OBJECTIVE AND IMPLEMENTATION

In response to the recommendations of the Working Group, the Director General decided that a survey should be conducted. The major objectives of the survey, as finally undertaken, were to determine the size and timing of the installation of nuclear power plants in each participating country that, for economic reasons, could justifiably be commissioned during the period of 1980 to 1989 (study period) and to determine the sensitivity of the results to certain key economic and technical parameters. Fourteen of these countries expressed an interest in participating in the survey and agreed to provide relevant basic data and provide counterpart staff to work with the visiting teams of experts. These countries are:

Argentina	Egypt	Korea	Philippines	Turkey
Bangladesh	Greece	Mexico	Singapore	Yugoslavia
Chile	Jamaica	Pakistan	Thailand	

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

The market survey project cost in total more than US $600,000 and was supported financially partially from the IAEA funds and staff but, also, substantially by cash contributions from the Federal Republic of Germany, the Inter-American Development Bank, the International Bank for Reconstruction and Development and the United States through its Agency for International Development, Atomic Energy Commission and Export-Import Bank. In addition numerous experts were provided on a cost-free basis by:

Canada	Japan
France	Sweden
Germany, Fed. Rep.	United Kingdom
India	United States

The participating countries contributed counterpart personnel and bore the expenses of each survey mission.

THE ANALYSES

Most of the data, on which the analyses were based, was provided directly by the countries concerned. Other data was developed by the survey staff and their consultants. A total of 26 experts qualified in various fields from the eight countries referred to above, and 11 Agency specialists assisted in this work.

The analyses included consideration of power flows in the basic inter-connected system under normal operating conditions, the possible differences in transmission system requirements under varying generating capacity plans, an analysis of the transient stability and frequency stability of each 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 of all costs for each plan. The results served as a basis for the selection of near-optimum power system expansion programmes for each of the countries. From these expansion programmes, the number, size and timing of nuclear power units required were determined. The financing required for the total thermal plant expansion programmes was also estimated.

It should be noted that the data acquired is not such as to allow the findings to be considered the equivalent of rigorously determined feasibility studies of any specific installations.

Table 1 shows the present and projected population and gross national product (GNP) for each of the countries studied. Forecasts of energy, demand and load factor for each country are summarized in **Table 2.** Two forecasts were considered for each country. The forecast prepared by the survey staff (usually lower than the country forecast) used a world-wide generalized correlation of electricity consumption per capita and GNP per capita. This assumed that each country's future electricity consumption will follow a characteristic path which depends on the historical relationship between these two factors. The country forecasts were taken as submitted by them. Where there were substantial differences between the forecasts analyses were made using both projections.

External costs were not taken into account, nor were taxes and restraints on foreign capital. The values of the economic parameters selected for the reference studies and for sensitivity studies are given in **Table 3.** In the sensitivity studies, the reference parameters were kept constant except for the single parameter being studied.

TABLE 1. SUMMARY OF POPULATION AND GNP

Country	Population[a] (10^6) 1972	1980	1990	GNP[b] (10^9 US $/yr) 1972	1980	1990
Argentina	24.0	27.3	31.8	28.9	45.4	73.2
Bangladesh	72.1	88.6	114.5	3.8	6.1	11.0
Chile	10.2	11.9	14.5	6.7	10.0	16.4
Egypt	34.7	40.6	49.5	7.4	11.9	21.5
Greece	8.9	9.3	9.9	10.6	17.3	29.8
Jamaica	1.9	2.2	2.6	1.3	2.2	4.2
Korea, Republic of	32.3	36.5	42.3	10.0	19.0	37.7
Mexico	54.2	71.5	96.0	39.4	68.3	129.3
Pakistan	55.7	65.2	79.5	11.3	17.9	31.7
Philippines[c]	20.7	25.2	30.9	5.7	9.9	18.7
Singapore	2.1	2.4	2.8	2.7	5.6	9.8
Thailand	38.3	48.6	62.5	8.3	15.1	29.2
Turkey	37.3	45.4	58.2	16.4	27.3	48.5
Yugoslavia	20.8	22.5	24.9	16.5	27.1	49.0

[a] Population forecast used for Market Survey forecast

[b] In 1 January 1973 US dollars (converted from 1964 US $ at a 4%/year inflation rate)

[c] Luzon only

TABLE 2. FORECASTS OF SYSTEM LOAD CHARACTERISTICS

Country[a]	Energy generation MWh × 10^6 1980	1990	Energy generation growth rate 1980 - 1990 %/year	System load factor (%) 1980 - 1990	Peak demand in MW 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	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	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[b]	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

[a] L = Market survey forecasts H = Country forecasts [b] Luzon only

TABLE 3. ECONOMIC PARAMETERS USED IN THE STUDY

	Reference studies		**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[b] fund	
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% per year

[b] This value was used for sensitivity studies in only a few selected cases

[c] See text 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 U.S. dollar in March 1973 was not taken into account in this study.

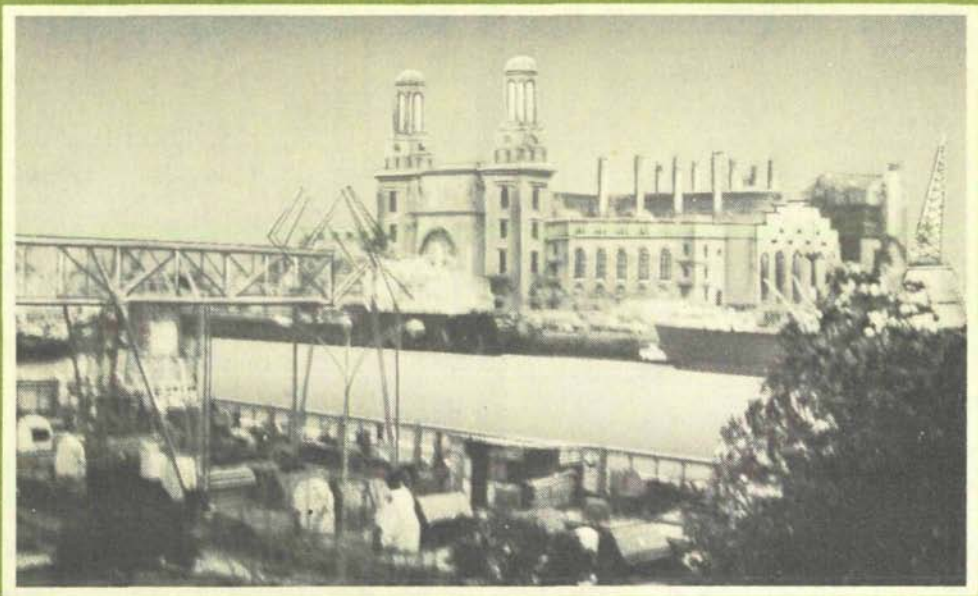
The present-worth of costs associated with each configuration was determined using a computer programme. This programme, called the Wien Automatic System Planning Package (WASP), estimated the capital costs of all plant additions and the operating costs of all plants during the period 1980-2000, less a salvage value in the year 2000. 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 lifetime, even though the study was specifically interested only in the first decade of this period. All costs were discounted to 1 January 1973, to determine the present worth of these costs.

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

The costing of environmental considerations in the participating countries was difficult to establish; therefore no allowance was made for these costs except that capital costs for fossil-fuelled plants included electrostatic precipitators to clean up particulate matter in 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 could increase and thereby influence the competitive relationship between fossil and nuclear plants. If the full complement of environmental control equipment were added to both nuclear and conventional plants it appears that the costs of fossil-fired plants would be increased substantially more than those of nuclear plants. This factor was not treated in a rigorous quantitative manner in these studies; however, a qualitative and approximate quantitative analysis was undertaken.

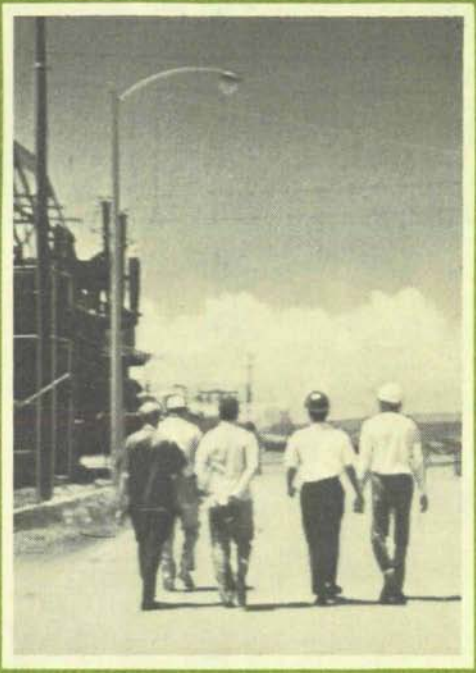
Sites visited by the Power Survey Mission...

This selection of photographs is from some of the 14 countries which were visited by the Power Survey Mission. Some are from our IAEA Photo Library files, sent by the Atomic Energy Commissions in the country concerned, and others are amateur momentos taken by members of the Survey Mission themselves.

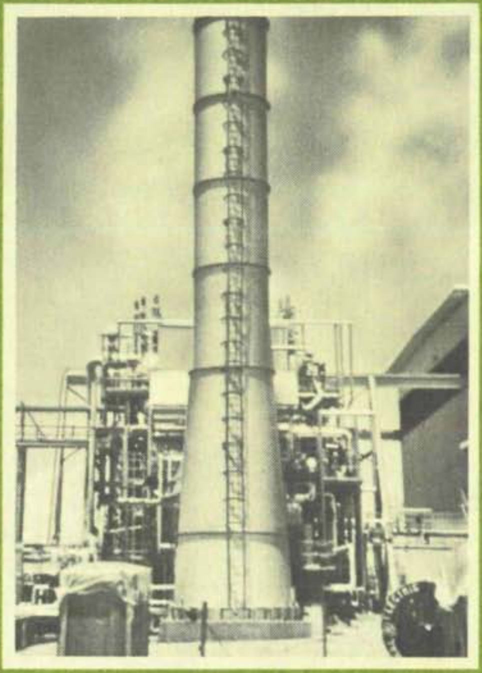


The Market Survey team which studied Argentian requirements, outside the Atucha Nuclear Power Plant.

The Puerto Nuevo Steam Plant, Buenos Aires, Argentina, visited by the Survey team.

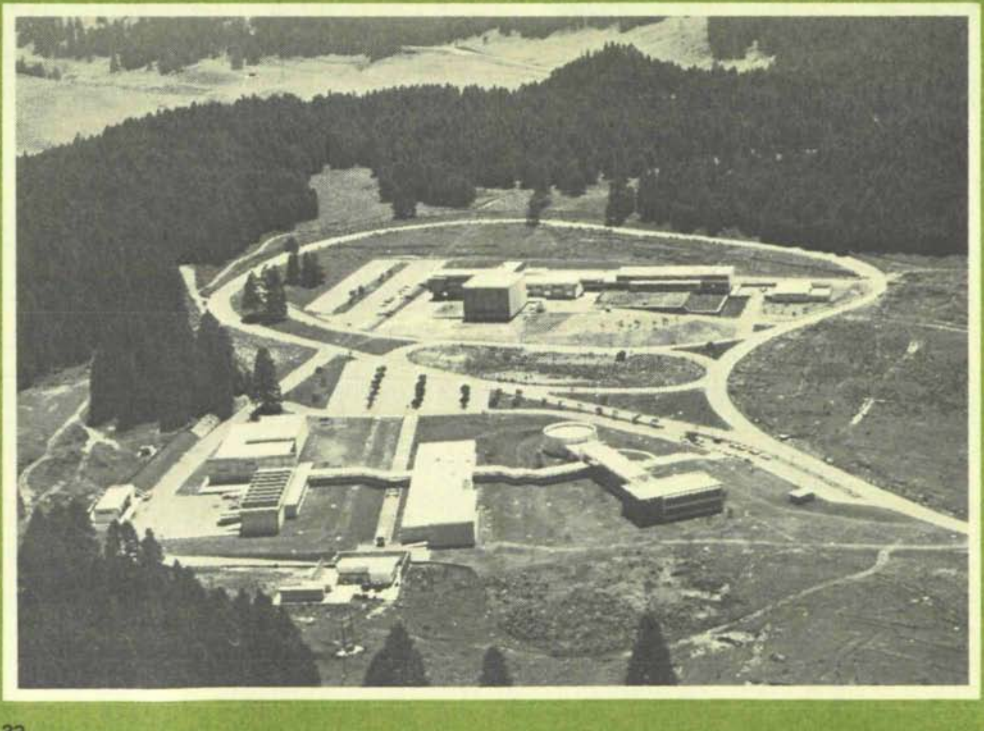


Members of the Market Survey Mission outside the "Old Harbour" power plant in Jamaica.



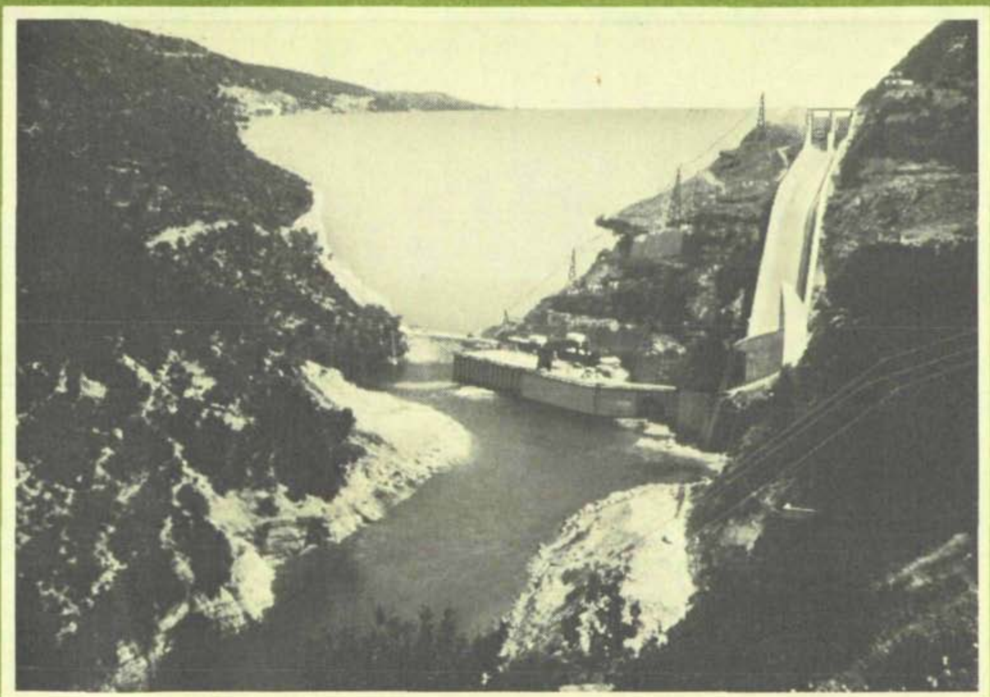
Unit No.3 of the "Old Harbour" power plant owned by the Jamaica Public Service Company, which the IAEA team inspected.

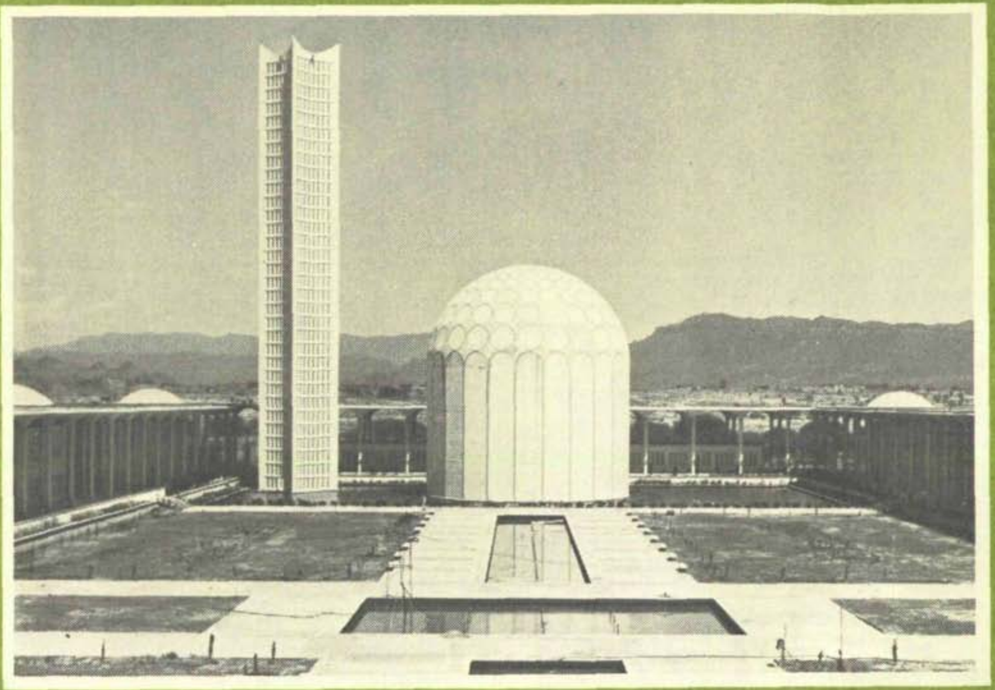
An aerial view of the National Institute of Nuclear Energy, Mexico.



The Kori plant construction superintendant explains the plant layout to the visiting Market Survey team in Korea.

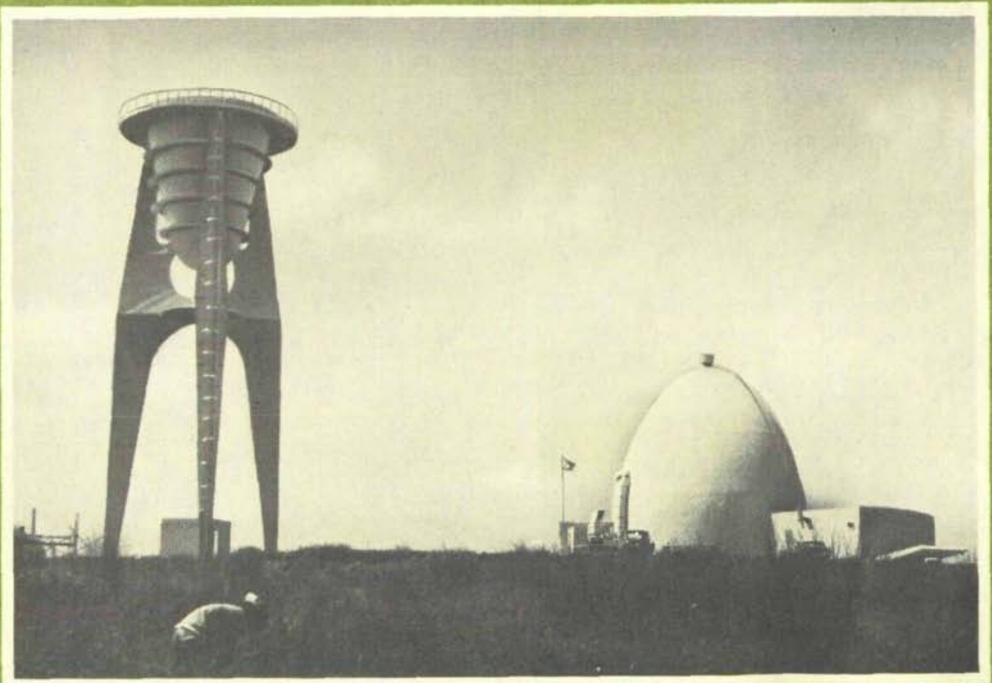
In Greece the Market Survey included the Kremasta Hydro Plant.





The Pakistan Institute of Nuclear Science and Technology in Nilore, Islamabad. The main research facility is a 5 MW research reactor which became critical in December 1965.

The Philippine Atomic Research Centre at Diliman, Quezon City, showing the water storage tank (left) and the reactor building (right).



CHARACTERISTICS OF POWER SYSTEMS EVALUATED

System capacities at start of study period

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.

Capacity additions during study period

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 (LOLP)[2] should be about 0.005. Having found the required total capacity additions, the capacity available from the installed hydro and pumped storage plants was subtracted to determine the required net thermal capacity additions. Such additions represent the total "market" for new capacity to be shared by nuclear and conventional plants.

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

[2] LOLP is defined as that percentage (or fraction) of time that the system cannot meet the expected load.

Capacity additions following study period

A single expansion plan for the 1990-2000 period was developed to meet the forecasted load growths for each country as referred to above. These expansion schedules were selected to provide essentially the same LOLP 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

These costs were determined by the ORCOST computer programme (see Table 3). ORCOST-1 costs are based on mid-1971 in the USA updated to 1 January 1973 by escalating equipment at 5% per year and materials at 15% per year. They show a ratio of nuclear to oil-fired plants of 1.4 to 1.8 depending on country and MW rating. ORCOST-3 costs include added costs reflecting recent sharp increases in nuclear plant construction costs in the USA up to 1 January 1973 with very minor changes in fossil-fired plant costs. They show a ratio of nuclear to oil-fired plant costs of 1.7 to 2.2 depending on country and MW rating. 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

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

(c) Other data

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/month). Where these data were available from a country it was used. Where the data was not available and, in special cases, standardized data were used for the evaluation.

PROJECTED NUCLEAR POWER MARKETS

The market for nuclear plants under reference conditions

The projected markets for nuclear plants which will be commissioned in each participating country during the study period are shown in **Table 4** based on the reference economic parameters. Also shown in the table are the percentage of total thermal market, for each country during the study period, which might be met by nuclear plants. This ranges from zero to over 95% with an overall average in the range of 70-75%. 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%.

One of the specific objectives for the market survey was to investigate the potential usage of small reactor power plants. Inquiries to the reactor manufacturing industry indicated substantially no interest in or acceptable price data on sizes below 400-600 MW. Nevertheless, a decision was taken to establish costs for sizes of 100, 200, 300 and 400 MW to use in the evaluation studies. 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 resulting from the studies was 200 MW and only a very few units in this size were indicated. The first size showing any appreciable market quantity was 300 MW.

The distribution of market by sizes of units

Table 5 shows the market for 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 (200-400 MW) 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.

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 24600 - 27600 MW drops to the minimum market level of 10200 - 10800 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 24600 - 31200 MW.

The potential market for large (800-1000 MW) nuclear plants, in contrast to the situation pertaining to small nuclear 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.

Studies were also carried out for several countries to evaluate the effect of varying other parameters. It was found that penalizing foreign exchange costs by using a shadow exchange rate of 1.1 to 1.3 had

TABLE 4. PROJECTED ANNUAL NUCLEAR PLANT ADDITIONS BY COUNTRY[a,b] IN MW

Country[c]	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total nuclear additions (MW)	Total thermal market (MW)	Nuclear % of total market
Argentina	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				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
Republic of Korea		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 (L)	600	1200	2200	4200	5500	5700	7900	5800	9000	10100	52200	71200	73.3
Total nuclear (H)	600	1200	2800	4400	5700	5700	10700	7800	10400	12800	62100	83350	74.5
Nuclear % 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 % 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 Market Survey (low load) forecast; H denotes market based on country (high load) forecast

[c] Market for unmarked countries (with one load forecast) were included in both low and high load totals

TABLE 5. POTENTIAL MARKET FOR NUCLEAR PLANTS IN MW

Size classification	Market under reference conditions[a]		Minimum nuclear market conditions[b]		Maximum nuclear market conditions	
	Low forecast	High forecast	Low forecast	High forecast	Low forecast	High forecast
Small (200-400 MW)	-	-	none	none	2 × 200	2 × 200
	4 × 300	5 × 300			11 × 300	10 × 300
	5 × 400	5 × 400			7 × 400	11 × 400
Sub-total	3 200	3 500	none	none	6 500[c]	7 800[c]
Medium (600 MW)	41 × 600	46 × 600	18 × 600	17 × 600	44 × 600	52 × 600
Sub-total	24 600	27 600	10 800	10 200	26 400[d]	31 200[d]
Large (800-1000 MW)	18 × 800	25 × 800	17 × 800	23 × 800	18 × 800	25 × 800
	10 × 1000	11 × 1000	10 × 1000	11 × 1000	10 × 1000	11 × 1000
Sub-total	24 400	31 000	23 600	29 400	24 400[e]	31 000[e]
Totals	52 200	62 100	34 400	39 600	57 300	70 000

Parameter conditions:		Discount rate		Oil price escalation rate
	a	8	and	2
	b	8	and	0
	c	8	and	4
	d	6	and	2
	e	6,8,10	and	2,4 (all combinations)

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%; on the other hand, use of a 2%/yr escalation rate on nuclear fuel prices would have lowered the market by about 8%.

FINANCING

Calculation of annual cash flows

In order to determine the year-by-year domestic and foreign investment requirements for the expansion programmes a special computer programme determined the annual domestic and foreign expenditures associated with each plant under reference conditions. 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.

Financing requirements for the total thermal plant expansion programmes include only the investment costs associated with the thermal plants added during the study period plus the nuclear fuel cycle working capital. It was found that with the low load forecast, domestic financing requirements amount to US $8251 million while foreign financing requirements reach US $12405 million. For the high forecast, corresponding amounts are US $9292 million and US $15157 million respectively. As mentioned above, costs refer only to those plants commissioned during the period 1980-1989.

The financing requirements for the nuclear fuel cycle investment were determined separately because the financing arrangements for these costs may differ from those for the plant construction. The investment associated with the nuclear fuel amounts to US $1262 $\times 10^6$ for the low forecast and US $1548 $\times 10^6$ with the high forecast. Essentially all of the nuclear fuel investment costs will be foreign.