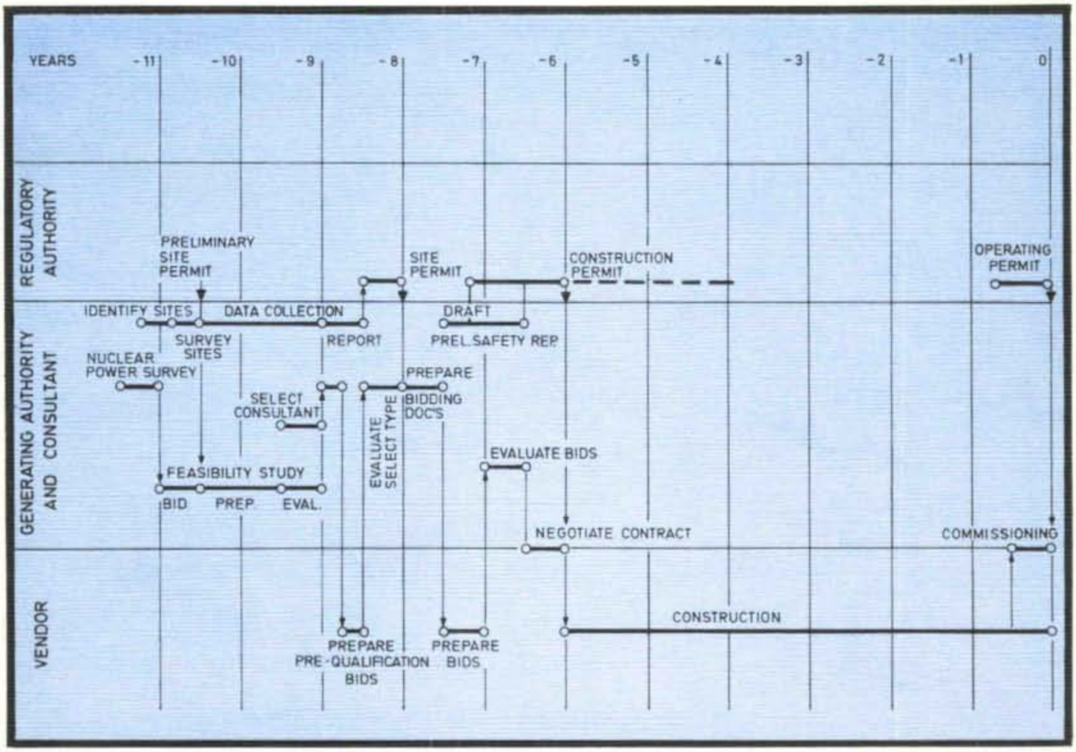


TECHNICAL REPORTS SERIES No. 164

Steps to Nuclear Power

A Guidebook

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1975

STEPS TO NUCLEAR POWER

A Guidebook

The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN
ALBANIA
ALGERIA
ARGENTINA
AUSTRALIA
AUSTRIA
BANGLADESH
BELGIUM
BOLIVIA
BRAZIL
BULGARIA
BURMA
BYELORUSSIAN SOVIET SOCIALIST REPUBLIC
CANADA
CHILE
COLOMBIA
COSTA RICA
CUBA
CYPRUS
CZECHOSLOVAKIA
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA
DENMARK
DOMINICAN REPUBLIC
ECUADOR
EGYPT
EL SALVADOR
ETHIOPIA
FINLAND
FRANCE
GABON
GERMAN DEMOCRATIC REPUBLIC
GERMANY, FEDERAL REPUBLIC OF
GHANA
GREECE
GUATEMALA
HAITI
HOLY SEE
HUNGARY
ICELAND
INDIA
INDONESIA
IRAN
IRAQ
IRELAND
ISRAEL
ITALY
IVORY COAST
JAMAICA
JAPAN
JORDAN
KENYA
KHMER REPUBLIC
KOREA, REPUBLIC OF
KUWAIT
LEBANON
LIBERIA
LIBYAN ARAB REPUBLIC
LIECHTENSTEIN
LUXEMBOURG
MADAGASCAR
MALAYSIA
MALI
MAURITIUS
MEXICO
MONACO
MONGOLIA
MOROCCO
NETHERLANDS
NEW ZEALAND
NIGER
NIGERIA
NORWAY
PAKISTAN
PANAMA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
ROMANIA
SAUDI ARABIA
SENEGAL
SIERRA LEONE
SINGAPORE
SOUTH AFRICA
SPAIN
SRI LANKA
SUDAN
SWEDEN
SWITZERLAND
SYRIAN ARAB REPUBLIC
THAILAND
TUNISIA
TURKEY
UGANDA
UKRAINIAN SOVIET SOCIALIST REPUBLIC
UNION OF SOVIET SOCIALIST REPUBLICS
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED REPUBLIC OF CAMEROON
UNITED STATES OF AMERICA
URUGUAY
VENEZUELA
VIET-NAM
YUGOSLAVIA
ZAIRE
ZAMBIA

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

Printed by the IAEA in Austria
April 1975

TECHNICAL REPORTS SERIES No. 164

STEPS TO NUCLEAR POWER

A Guidebook

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 1975

STEPS TO NUCLEAR POWER: A GUIDEBOOK
IAEA, VIENNA, 1975
STI/DOC/10/164
92-0-155175-4

FOREWORD

The International Atomic Energy Agency, in response to many requests, has produced this guidebook as a general summary of the work that has to be undertaken in the preparation for and introduction of nuclear power in a country. In particular, the book gives guidance on the decisions that have to be taken and the requirements for studies, organization and trained manpower that have to be met on the path to the first nuclear power plant.

The guidebook is intended for senior government officials, policy makers, economic and power planners, educationalists and economists. It assumes that the reader has relatively little knowledge of nuclear power systems or of nuclear physics but does have a general technical or management background. Nuclear power is described functionally from the point of view of an alternative energy source in power system expansion.

The guidebook is based on an idealized approach. Variations on it are naturally possible and will doubtless be necessary in view of the different organizational structures that already exist in different countries. In particular, some countries may prefer an approach with a stronger involvement of their Atomic Energy Commission or Authority, for which this guidebook has foreseen mainly a regulatory and licensing role.

The recent increase in oil prices will undoubtedly cause the pace at which nuclear power is introduced in developing countries to quicken in the next decade, with many new countries beginning to plan nuclear power programmes. It is intended to update this booklet as more experience becomes available. Supplementary guidebooks will be prepared on certain major topics, such as contracting for fuel supply and fuel cycle requirements, which the present book does not go into very deeply.

CONTENTS

Page

ANNEXES

1. THE NEED FOR NUCLEAR POWER

Early industrialization was based on the availability of inexpensive energy, in some cases hydraulic, in other cases readily available coal. Coal was the most important initially, as it was used in steel making, both as an energy source and as a reducing agent. Development of natural water basins close to populated areas soon followed as the requirements for power increased. The processes for using and converting the primary energy forms have been developed very far and this had led to an ever increasing importance of the secondary energy forms, particularly electric energy, which are convenient to the final consumer. In most countries electricity consumption doubles at least every ten years; in some the doubling period is as short as five years.

Energy is needed for all development and the per capita consumption of primary energy forms and of electricity can be used as a measure of development as shown in Figs 1.1 and 1.2 based on data from the UN Statistical Yearbook 1971. These also indicate the drastic increases in energy consumption which will be needed to bring the developing countries with their very low per capita consumptions and often large population to the same level as the industrialized societies.

Figure 1.3 shows the natural or primary energy sources that are available. They are generally utilized after conversion into useful energy forms, and each conversion process has associated with it conversion losses.

Even disregarding the present acute energy situation, there have been many reasons why nuclear power was known for many years to be required in helping to meet the energy needs of our societies. First, the reserves of fossil fuels (oil, coal and gas) are not unlimited and there is concern about their present rapid rate of depletion. The regenerative sources are either not sufficient to cover more than a fraction of the global needs (wood, hydro, tidal and wind energy) or technology has not been developed to use them efficiently (solar energy). The fossil fuels also represent valuable raw materials for petrochemical and other industries for future generations. Uranium resources in the world, if used as fuel in advanced reactor types, contain many times the energy of all the known fossil fuel reserves. Second, nuclear power plants are now economically competitive with fossil-fuelled plants over a range of sizes and should thus be considered as alternatives for economic electricity production. Third, the introduction of nuclear power in a country will also mean a diversification of energy supply which in itself may help to stabilize energy prices over longer terms. The sharp increase in oil prices which occurred in late 1973 and early 1974 has, of course, further stressed the importance of nuclear power as an alternative energy source, and made it economically competitive with oil for base load electricity production in all unit sizes above 150 MW(e).

1.1. What is nuclear power?

A nuclear power conversion system converts the energy of nuclear fission into electricity. Isotopes of certain heavy elements (uranium and plutonium) can undergo fission and release energy: The amount of energy released per unit weight exceeds that which can be obtained from fossil fuels by many orders of magnitude. In present, proven reactor types,

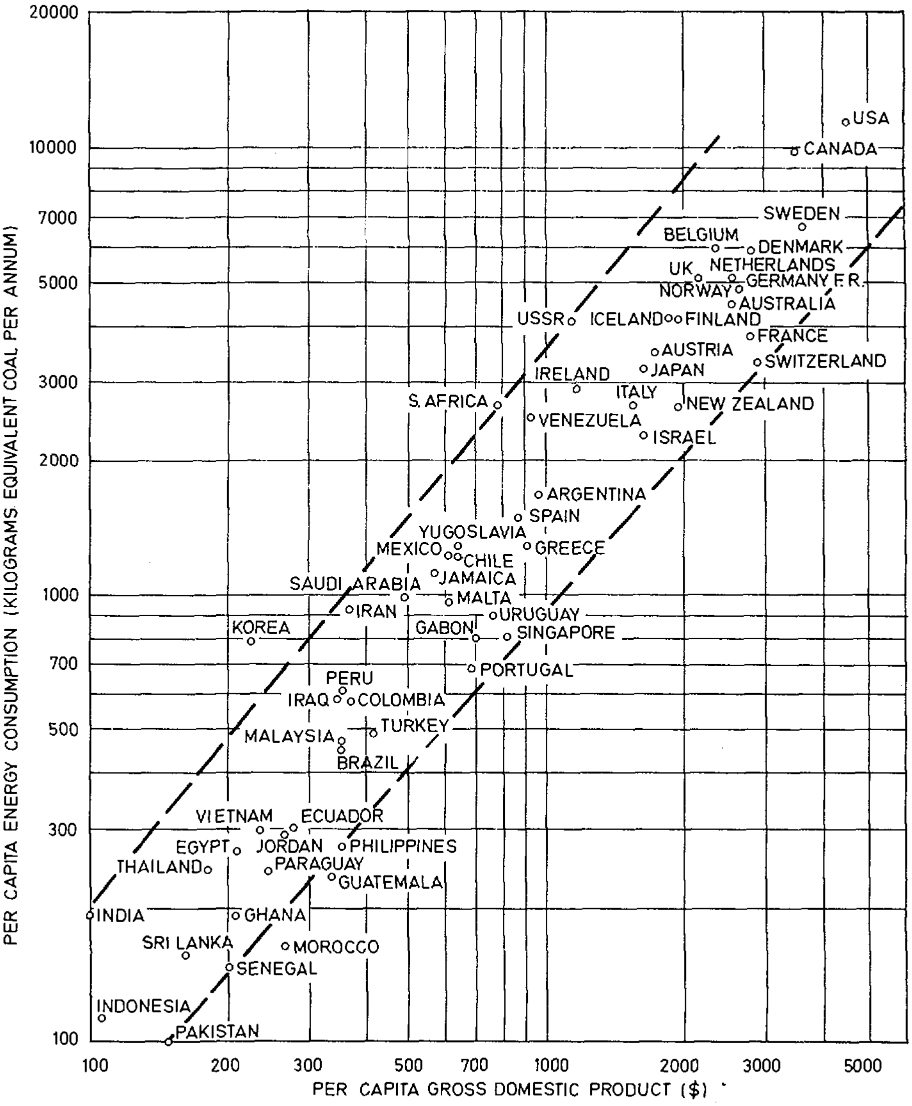


FIG. 1.1. Per capita energy consumption as a function of the per capita gross domestic product (Source: UN Statistical Yearbook, 1971).

1 kilogram of slightly enriched uranium fuel produces as much heat as 35 tons of coal, and this ratio could be raised by a factor of about 50 in more advanced nuclear stations. The energy is released mainly in the form of heat, which in the present reactors is used to convert water into steam. The steam is then expanded through a turbine which drives a generator in the same manner as in a conventional fossil-fuel-fired station. As in a conventional station, a nuclear system creates by-products and

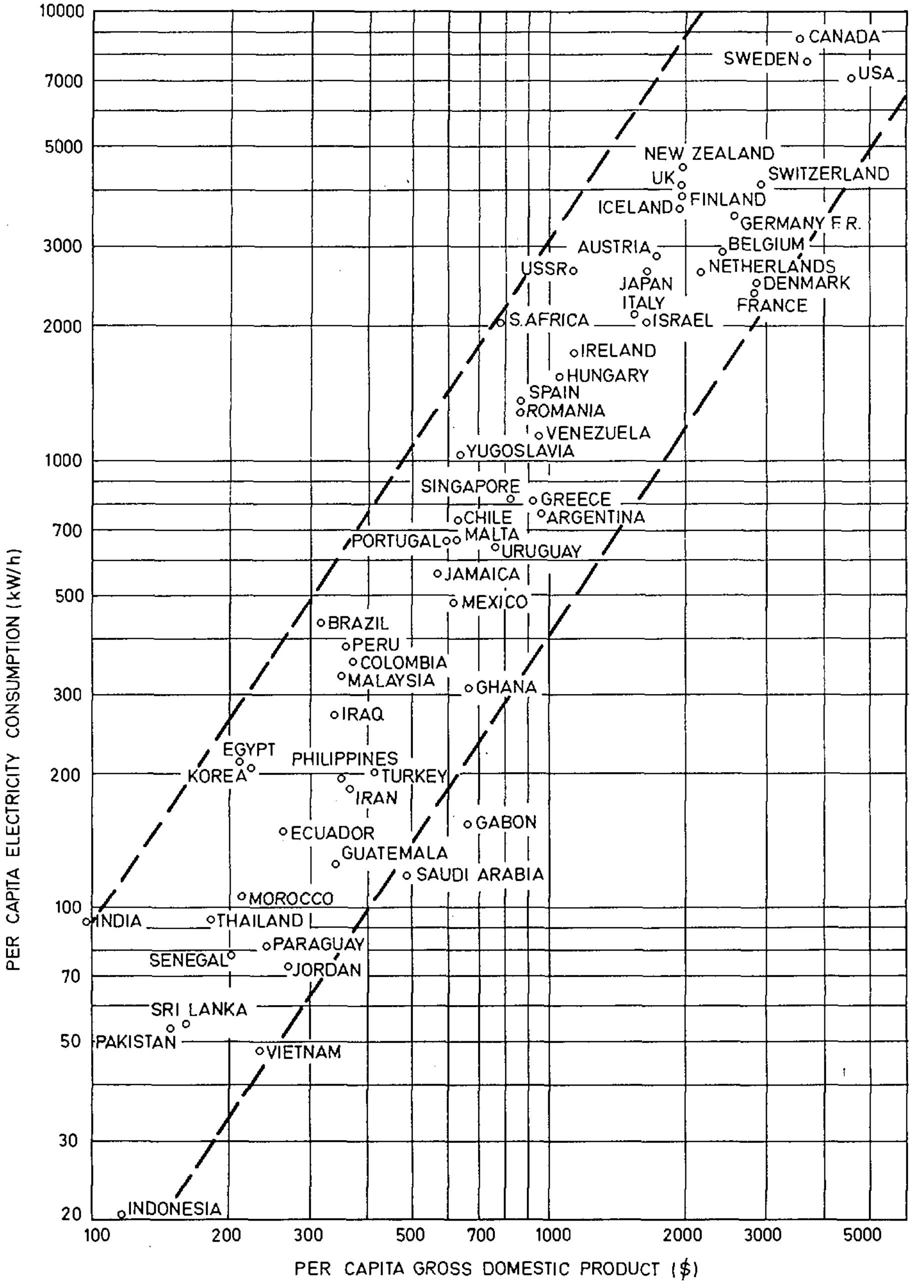


FIG. 1.2. Per capita electricity consumption as a function of the per capita gross domestic product (Source: UN Statistical Yearbook, 1971).

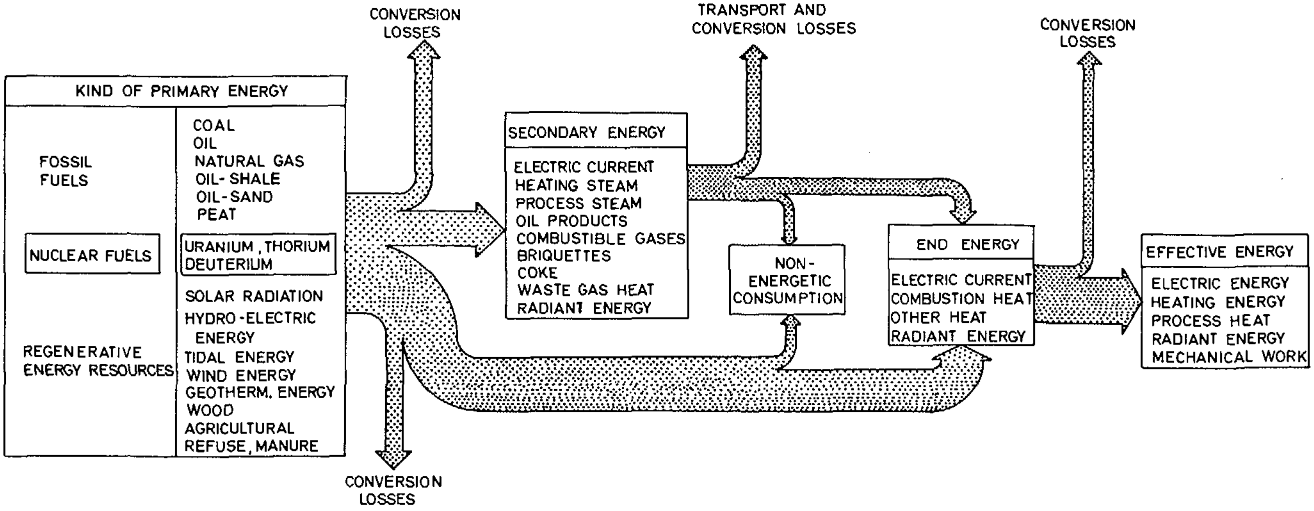


FIG. 1.3. Resources of primary energies and their conversion into effective energy (Source: Peaceful Uses of Atomic Energy, Proc. 4th Int. Conf. Geneva 1 (1971) 448).

waste. Instead of producing ash, the nuclear process gives a variety of highly radioactive materials which must be contained against release to the surroundings. New fissile materials are also created as the initial ones are utilized. It is usually economical to reprocess the irradiated fuel by chemical dissolution for recovery of the unburnt fissile material and for disposal of the radioactive wastes.

The fission process in nuclear fuel determines the basic structure of the core of any nuclear power plant in which the heat produced by the fission is to be usefully extracted and transferred directly or indirectly to a generator through the medium of steam or gases.

The nuclear fuel is contained in a leak-tight metal sheath, typically a zirconium alloy tube. Several such tubes are kept together in a fuel assembly and a number of fuel assemblies form the reactor core, which is in turn contained in a pressure vessel, either in the form of a thick-walled steel vessel or a number of pressure tubes.

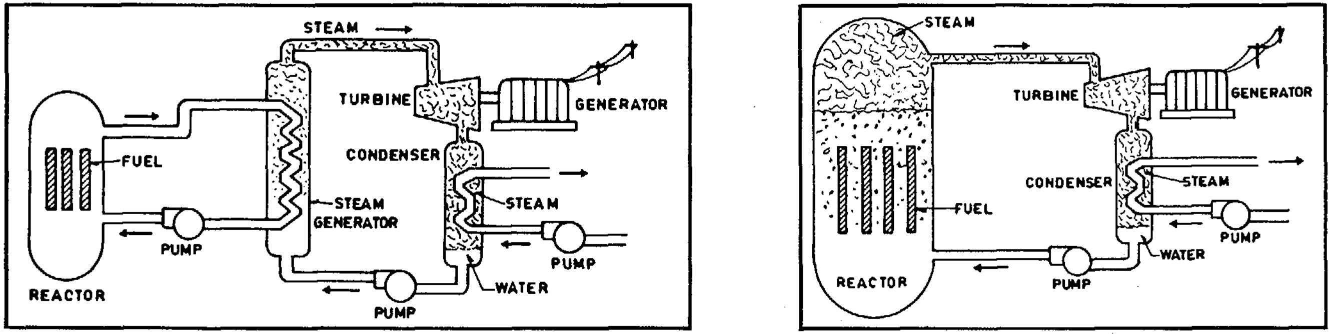
In order to reduce the concentration of fissile material needed to sustain the fission process, a moderator is used to slow down or moderate the neutrons which are given off in each fission and carry the process further in a chain reaction. Substances such as water, heavy water or graphite are used as moderators. The fuel has to be cooled and the coolant can be either liquid or gaseous: water, heavy water, carbon dioxide, helium or liquid sodium. It can be taken either to a heat exchanger where steam is generated in the secondary side (indirect cycles), or steam can be generated directly by boiling water in the reactor core (direct cycle boiling water reactor). A number of auxiliary circuits are used in all designs to purify or maintain the proper chemical composition of the working fluids and to make up losses through leakage. Finally, a system for changing the fuel is required. This again varies greatly with different designs. Figure 1.4 gives a schematic representation of some power reactor types.

From a safety point of view the basic characteristics of a nuclear power station are:

(i) The large amount of radiotoxic material which will build up within the core of the reactor (of the order of 100 million curies), while at a level of the order of microcuries, is potentially already dangerous.

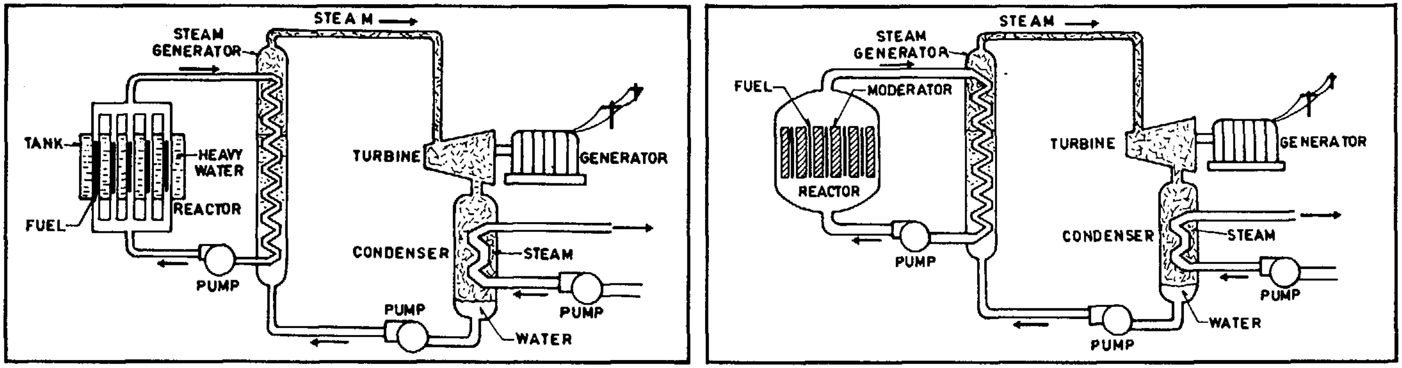
(ii) The chain reaction can be shut down, but a non-negligible amount of heat, the decay heat, will continue to be released in the core. The decay power is of the order of a few per cent immediately after shutdown. This means more than 100 MW thermal for a station of 600 MW(e) electrical output. After some months, the decay heating will still be of the order of 0.01% of the full power of the reactor.

The design of the reactor is very much affected by these phenomena. Sophisticated systems of multiple barriers, one following the other up to the containment systems, are provided by the designer so that dispersion of the radiotoxic material cannot take place even in the case of accidents when some of the barriers are damaged. Furthermore, very sophisticated systems are provided to cool the core under any circumstances, including all normal shutdown conditions and very severe accident conditions which are assumed as reference for the design. For all these reasons safety



Schematic diagram of a typical pressurized-water reactor (PWR)

Schematic diagram of a typical boiling-water reactor (BWR)



Schematic diagram of a typical heavy-water reactor (HWR)

Schematic diagram of a typical gas-cooled reactor (GCR)

FIG. 1.4. Schematic diagram of power reactor types (Source: Nuclear Power and the Environment, IAEA, Vienna (1973)).

and control measures play a particularly important part in nuclear plant design, since an accident would not only interrupt reactor operation but the surrounding area must also be protected from risk of radioactivity release. Nuclear plant design is thus based on the most stringent requirements for safety and protection. Quality control under construction is unsurpassed in projects of the magnitude of nuclear power stations. It is thus not surprising that nuclear power plants cost more in capital and require longer construction times than their conventional counterparts. Furthermore, the personnel of a nuclear power plant must also be very well trained because operational errors could not only cause economical losses but also create dangerous situations for the personnel itself and to the surrounding area.

1.2. Projections of installed capacity

Before proceeding to national considerations, it might be interesting to look at the present and future status of energy consumption in the world at large.

Figure 1.5 summarizes recent projections of total installed electrical capacity in the world up to 2000 according to a recent IAEA forecast. The curve shows an initial doubling time of just less than ten years, i.e. a 7.7%

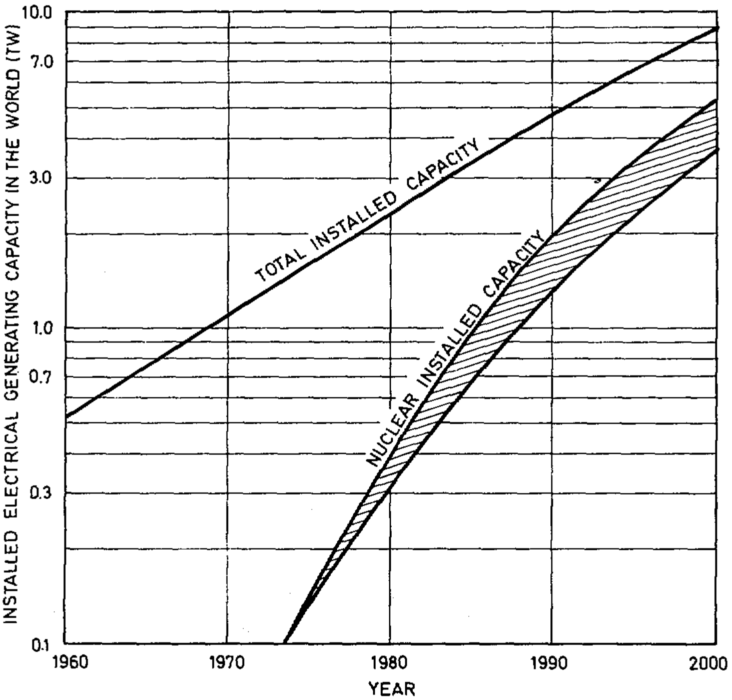


FIG. 1. 5. Forecast of nuclear generating capacity in the world to the year 2000.

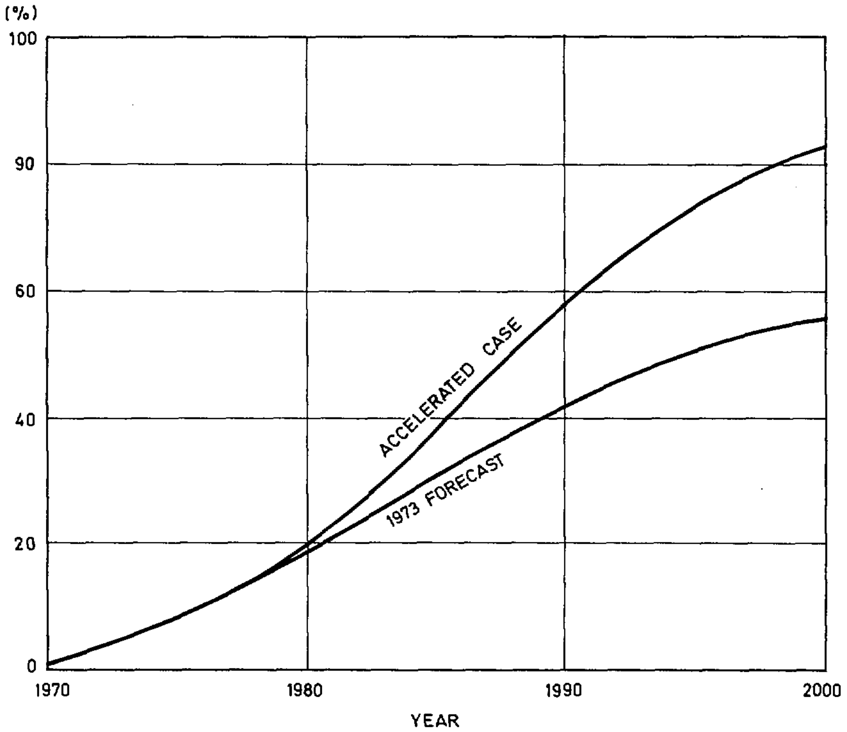


FIG. 1. 6. Forecast of the nuclear share of total electricity generated to the year 2000.

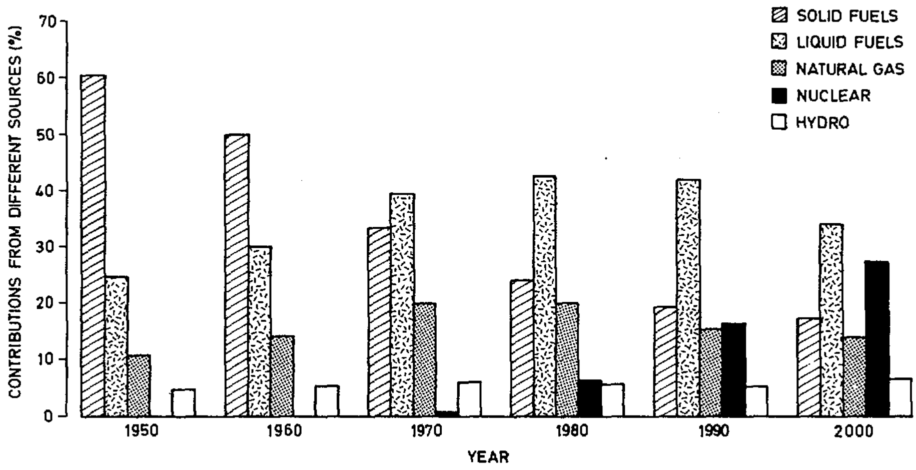


FIG. 1. 7. Contributions of various primary energy sources to electricity generated to the year 2000. (With reference to the 1973 forecast.)

annual increase which in 1990-2000 tapers off to an annual increase of 7.0%. The share of the developing countries in the world total electrical capacity is projected to increase only from about 11% in 1970 to about 25% in 2000. Since the developing countries have about two-thirds of the world population, this means that, according to this projection, they would be catching up with the industrialized countries only very slowly. Since they often have higher population increase rates than the industrialized countries, the rate of catching up in per capita capacity is even slower than the curves would indicate. Annex 1 gives a more detailed discussion about energy demand development in the developing countries.

The projection of nuclear capacity shows a very rapid increase from the mid-1970s until nuclear energy is expected to produce some 55% of all electric energy in the world in 2000, which would then mean that nuclear energy would be the second largest primary energy source, surpassed only by oil. The current energy situation has caused many countries to revise their nuclear power programmes upwards. Figures 1.5 and 1.6 also show the present estimate of an accelerated use of nuclear power, according to the same 1974 IAEA forecast referred to above.

It should be kept in mind that there are considerable uncertainties in these estimates. While we now can make fairly precise forecasts up to 1985 based on orders and national commitments, the estimates for later years are obviously much less precise and should be used only to show trends. Nevertheless, it is clear that nuclear energy is expected to play a major role in the world's future energy supply (Fig.1.7).

1.3. Alternative sources of energy

(a) Water

Natural water reservoirs have served to establish the major electric power grids of the modern world. In many countries, however, further expansion of hydroelectric power has been limited by the high capital costs of developing reservoirs that are in remote places or of low power potential. Still, if present oil prices prevail, many of these hydro projects will become economically competitive with oil-fired plants, and hydro power will continue to be important in many countries in the 1980s. In the hydro range, hydro power is still expected to contribute only some 5-6% of the primary energy and major expansions will have to be based on nuclear plants.

(b) Coal

The world's coal resources are sufficiently large to supply the world's energy demand for more than 100 years. However, coal production costs are very sensitive to both geologic conditions and labour wages. They may vary from US $3 to more than US $30/t, i.e. from US $0.4 to more than US $4/Gcal[1.1]. Since also coal transportation costs are high, coal prices vary substantially from one region to the other. In many regions, coal was unable to compete with oil in the 1960s, and the relative importance of coal has steadily decreased in the past decade. The recent oil price

---

[1.1] 1 Gcal = 10^6 kcal.

increase may change this trend in the future, particularly if coal gasification and liquefaction techniques can be economically applied on a large scale. The now desired substantial increase in coal production, however, will suffer from considerable time lags which are necessary before exploiting new coal fields.

(c) Oil

The production and transportation costs of oil are very low as compared with coal production costs, and they are insensitive to labour costs. These facts and the ability to quickly meet the growing energy demand have been strong incentives to increase rapidly the world-wide oil production.

The ultimate depletion of limited oil reserves has often been quoted as a reason for the introduction of nuclear power. In the long run and on a global scale it is true that oil resources seem to be much more limited than coal, and it is also true that the hydrocarbons in oil have a great value as raw materials for chemical industries; this, of course, further stresses the undesirability of simply burning limited resources for power production. While these considerations constitute a valid warning and could form part of the basis for national policies, they have, however, not been applied in the planning of the expansion of individual electricity systems, and oil has in the past decades set the standards of economics for new power stations. The almost stepwise increase in oil prices in 1973 to the present level of US $70-90/t, i.e. US $7-9/Gcal, has, of course, drastically changed this situation, and for new electricity generating stations oil would no longer be competitive with nuclear fuels in station sizes above about 150 MW(e), if nuclear plants were available in that size range.

(d) Natural gas

Natural gas has become of great importance in some areas, and globally its contribution is about 20% of primary energy consumption. Still, essentially the same considerations as were stated for oil apply also to natural gas. Ultimate resources are also estimated to be more limited than those of oil. While, for natural gas, ease of transport over fairly short distances in pipelines and the convenience of using it have been great assets which have promoted the very rapid increase in gas consumption, a more general use would require transport in liquid form in specially equipped tankers.

Due to higher long-distance transportation costs, natural gas costs will differ more than oil costs from one region to the other. Where natural gas is an indigenous resource and could be cheaper than other primary energy sources, its price will generally be oriented towards the equivalent price of its main competitor. Thus, prices will tend to rise and, furthermore, the limited reserves will restrict the relative world-wide importance of natural gas.

(e) Uranium

A nuclear power station mainly uses uranium as fuel. It is true that plutonium is being used in small quantities and thorium may also become important in the future, but at present, and for the planning period of some 10-15 years under consideration here, it is sufficient to only consider the uranium reserves and prices.

The future supply of uranium has to be considered against a background of forecasts of uranium demand over the next decades which show increases of a spectacular nature. A world survey by the Joint NEA/IAEA Working Party on Uranium Resources, Production and Demand, completed in 1973[1.2], indicates that from a present production level of just over 19 000 tons production requirement will increase to 50 000 tons uranium by 1980, 100 000 by 1985 and 180 000 by 1990. Few, if any, mineral production industries have been called upon to plan for a near tenfold production increase in a space of about 15 years, as these forecasts imply.

The NEA/IAEA study shows that present "Reasonably Assured Resources" in the less than US $10/lb U_3O_8 category amounted to 866 000 tons of uranium in mid-1973. In addition, there are 670 000 tons of reasonably assured resources in the US $10-15/lb U_3O_8 price category. The estimated additional resources which are not yet proven may double these figures.

If all the present low-cost reserves (i.e. 866 000 tons) could be used up in time (which is improbable), they would be just sufficient to provide fuel up to approximately 1987, but if a forward reserve equivalent to eight years' consumption is maintained to assure supply at the projected rate, a satisfactory reserve situation would only be maintained up to around 1979.

Because of the physical nature of ore bodies and dependence on production of other metals (e.g. gold in South Africa, copper and phosphate in the United States), not all the presently known reserves could be made available by 1987. In view of the market situation it is also probable that little effort will be made to develop existing reserves in the higher cost range in time for production before 1987, and this will further limit the availability of these resources. Availability will, however, depend on the evolution of prices and the related growth of production in the intervening period.

Other potential sources of uranium can be drawn upon in addition to known reserves, for example, an estimated 70 000 tons of uranium could be recovered in the United States as a by-product of phosphate and copper production by the end of this century. Six hundred seventy thousand tons of uranium estimated in the US $10-15/lb U_3O_8 reasonably assured category would also be available if the price of uranium were to increase into this range. However, nearly half of this higher cost material is in Swedish black shales and, according to Swedish authorities, production from this source will be restricted to helping meet only Sweden's needs.

Uranium at costs of US $15 per pound U_3O_8 or more may well be used in the present generation of water reactors, and an increase of the uranium price will only have a small effect on the kWh price (a US $10 increase per lb in U_3O_8 price would only correspond to 0.7 mills/kWh or an increase of 7%). The effort to develop the capability to produce the quantities of low-grade ore equivalent to such a price will, however, not begin until there is positive indication of a market at that price.

Further caution is needed regarding estimates of low-grade resources. A high proportion of the high-cost resources are in the same deposits as

---

[1.2] OECD/NEA-IAEA, Uranium Resources, Production and Demand, Paris (August 1973).

the lower cost material. So long as mining continues at the cutoff appropriate for lower costs, much of the higher cost material will be lost entirely or become even more costly for later recovery. On the other hand, it is recognized that the estimates of US $15 uranium are probably conservative for lack of data because industry's effort has, up to now, been directed to the development of higher grade ore.

Because of the long lead time of some 8-10 years, needed to develop any large low-grade deposit, and the prevailing low prices which will probably not exceed US $10 for the next decade, substantial production cannot be expected from such sources during the next 20 years when requirements will be the largest.

Fortunately, there are extensive, apparently favourable areas that have not yet been prospected. Although many of these are remote, the obstacles to exploration can probably be surmounted in much the same manner as they have been in the development of the Niger deposits. Undoubtedly, future exploration will continue to focus on Africa, parts of Asia and on Australia where many important new finds have recently been made.

Although a situation of oversupply is periodically encountered in the mineral industries, it is hard to draw a parallel with the uranium case when confronted with an exceptionally high growth in which a doubling of annual uranium requirements in five years is forecast. The magnitude of this challenge is brought more clearly into focus when viewed in the context of the lead times necessary for exploration and subsequent preparation of new production facilities.

In summary, no shortages of uranium supply are to be expected in the 1970s. However, the rapid growth in demand in the coming decade cannot be satisfied on the basis of existing uranium exploration levels. Given the necessity of a lead time of about eight years between discovery and actual production, it is therefore essential that steps be taken to increase the rate of exploration for uranium so that an adequate forward reserve may be maintained.

(f) Other primary energy forms

There are several other energy resources which may play a significant role in the future. The conventional ones are lignite, tar sands and oil shales. There are many large lignite deposits in the world but the major drawback is that lignite has high moisture and ash contents, and transportation costs thus become high. Lignite is, therefore, used chiefly in power plants located at the mines and with this restriction utilization of the deposits becomes a question of the possibilities of economic transmission to the consumers of the produced power. The high oil prices, however, have considerably enhanced the possibility of increasing future use of lignite.

While the total petroleum reserves in tar sands and oil shale on a global basis are far greater than in the oil fields, both are difficult to recover economically with present techniques. High oil prices may, however, force a greater utilization of tar sands and oil shale.

The non-classical energy resources most often referred to are geothermal, solar, wind and tidal energy and fusion. There has been considerable discussion recently about the potential of geothermal energy with very widely varying estimates, but the major limitation at the present time seems to be that easily accessible geothermal sources generally occur only in volcanically active areas and their combined potential is fairly small. In the early 1970s only about 1300 MW(e) installed capacity was geothermal. Ultimately it may become possible to obtain energy from the hot rock in the earth's interior, but the techniques for this are not available now.

Solar energy has a gigantic potential but the major problems are the low conversion efficiencies and consequently large areas and very high capital investments required with our present techniques. Wind generators have been built for a long time but the present largest projected sets have capacities of only about 5 MW(e). Both these energy sources would in most places have the disadvantage of uneven production and would thus require energy storage facilities. Tidal power is demonstrated but has a low overall potential, of the order of some per cent of the available hydro power potential.

Energy from fusion of light atoms bears a great promise for the future but the first fusion reactor still has to be built and it is not estimated that fusion will be available for power production on a large scale until after 2000.

In summary, while all these energy sources have some potential, they must at the present time and with our present techniques be considered as having possibly important local applications but only small overall significance at best for the next couple of decades. The only alternative energy source which is available now is nuclear fission and from the global picture it is clear that it is urgently needed.

1.4. Reasons for considering a nuclear power programme

In 1972-73, the IAEA performed a market survey for nuclear power in 14 developing countries. It clearly showed that even with the then foreseeable oil prices nuclear power reactors would become competitive and a total nuclear generating capacity of about 55 000 MW could be forecast on strict economic grounds to be installed in these 14 developing countries during the 1980s[1.3]. The increase in oil prices in the last quarter of 1973 has, of course, significantly improved the competitive situation of nuclear power. An up-dating of the market survey would now indicate that the 14 countries would need some 86 000 MW of nuclear generating capacity during the 1980s and extrapolating to all developing countries in the world the nuclear capacity to be installed could be some 220 000 MW by 1990. This must, however, not be taken as a forecast as in that capacity some 45 000 MW in 150 units of less than 600 MW would be included and these are not commercially available on that scale. Furthermore, the market survey could not take into account additional hydro potential which now would be economical, or the delays in load growth which have occurred.

Two major reasons for considering the introduction of a first nuclear power station stand out:

- If a large base-loaded thermal power station is needed for the system expansion, a nuclear fuelled station should be considered as a possible,

---

[1.3] INTERNATIONAL ATOMIC ENERGY AGENCY, Market Survey for Nuclear Power in Developing Countries: General Report, IAEA, Vienna (1973).

economically competitive alternative to fossil-fuelled plants and the IAEA market survey has clearly shown that economics justify consideration of nuclear power stations; and

- The introduction of a new fuel in the power economy may, in spite of its possibly small rôle in the total energy balance, have an overall stabilizing effect on the prices of the other fuels.

The two reasons given above are most important to the electricity generating authority or utility which is likely to own and operate the plant eventually. There are, however, also other reasons of a political or national economics nature which should be considered, often on a government or ministerial level as matters of national policy, which may finally also influence the decision whether or not a first nuclear power plant is to be built. Some of these reasons, discussed in the following, may be more or less valid in specific situations but experience has shown that particularly in developing countries they can well have great importance.

The long-term depletion of indigenous fuel reserves has already been mentioned as one possible consideration for the long-term energy policy of a country. It must, however, be recognized that reserve estimates of, e.g. oil, may by their very nature considerably underestimate real future reserves which may be expanded not only by prospecting but also by improving recovery techniques.

It is also worth considering that even in an oil exporting country, the introduction of nuclear power may mean, with current oil prices, higher total revenues for the country over a long term.

The existence of domestic uranium resources will presumably influence policy making not only in regard to the introduction of a nuclear power programme but also concerning the type of reactor and fuel cycle that will be chosen. The choice of the reactor system and associated fuel cycle is generally one which should be made against a background of long-term national policy.

An often discussed aspect is the "technological fall-out" of a nuclear power programme for a country. Although sometimes its importance may have been overstressed, particularly for those developing countries which would be forced to import almost all plant equipment because of lack of domestic industrial capabilities, there is no doubt that the first nuclear power plant will have a considerable impact through its requirements for trained staff at all levels, from management and engineers to welders and fitters. If an effort is made to get as great a local participation as possible in the construction work, the impact on the local industry will be in terms of improved capability to work to strict specifications on a project which in magnitude would surpass any other task undertaken in the past. It will also be probable that local industries will undertake work which has not been performed at all before, such as precision welding of stainless steel. This will require the creation of a new skilled labour force, which will prove very valuable in the future development of industry. The undertaking of a nuclear power project will also place very strict demands on higher management introducing new management techniques, e.g. in planning, and this should again be highly beneficial for the development of domestic industrial capability.

At the same time high importance must also be given to the very great capital requirements of a nuclear plant and in particular the large foreign exchange component, which naturally will stress the influence of the financing terms that can be obtained (Section 5.5). In some countries nuclear power plants may be given favourable consideration as a first step towards future large dual-purpose plants to produce electricity in conjunction with heat for an industrial process or for desalting water on a large scale.

A nuclear power station may have definite advantages with regard to environmental impact. Due to the present lower efficiency of nuclear compared to fossil-fuelledplants, the discharges of waste heat for a nuclear plant will be up to 50% higher than for a fossil-fired plant of the same size, but the nuclear plant is not associated with any of the major air pollutants which emanate from the burning of oil or coal. In normal operation there are minute quantities of radioactive effluents from a nuclear plant (Section 2.6), but nuclear power is still the cleanest way to produce electric energy.

In case of an accident, however, the two stations behave in a completely different manner. A very severe accident in a conventional station may cause limited damage to the immediate proximity of the plant, while a severe accident in a nuclear station, if not very well contained, may release radiotoxic material into the environment and have grave consequences. To avoid such an accident, a nuclear power station must be designed, constructed and operated so as to minimize the probability of accidents and be provided with additional systems (engineered safety features) which would in any case mitigate the consequences of accidents.

For these reasons, when a country decides to embark upon a first nuclear power station, it must also make a commitment to policy to:

- Ensure that the highest quality levels and standards are used for design, construction and operation;
- Provide for highly qualified and well-trained staff for the project at all stages; and
- Establish a legislative framework and a regulatory authority which through reviews and inspections can ascertain that very high standards are established and maintained.

Theoretically, the risk of severe accidents with a nuclear power plant exists, but practical means also exist to reduce this probability to very low values through this policy commitment so that the risk is acceptable to the community.

Finally, the first nuclear power plant should never be considered in isolation and as one individual plant only. It should, particularly at the national policy level, be regarded as the first commitment in a long-term nuclear power programme, with a planned continuation of several plants. The first plant can be regarded as the most important step and it is obviously desirable that it should show the way towards the future and conform with national goals for the future fuel cycle and industrial development.

1.5. First organizational steps

The background given in this Section has served to demonstrate that, at some point in time, nearly every country should begin to consider nuclear power. The problem then arises of when and how to begin. The timing is obviously very important as a period of 9-11 years should be allowed for preparations and training before the first nuclear plant can go into operation; too long a time of preparation has disadvantages as nuclear power organizations may be set up too early and constitute a drain on the available qualified staff.

One way for the government authorities to obtain neutral advice on when to start organizational steps is to call for an IAEA nuclear power planning study (Section 1.7).

The question of how to start considering nuclear power alternatives must be answered individually for each country as the organization for generating and distributing electric power, for industrial development and planning, and for research and atomic energy promotion is set up differently. Each of these authorities would have a direct interest in nuclear power. Other organizations, such as central banks and trade commissions have an indirect interest, and should be aware of and understand the aspects of nuclear power generation that are within their sphere of interest.

Historically, government organizations such as atomic energy commissions and authorities have been responsible for the development of nuclear power stations due to their experimental and prototype nature. Now nuclear power has, however, come of age. Reliable nuclear power generation systems are commercially available and economic principles can be exercised in their procurement. Scientific expertise will still be needed to provide the background for policy decisions about the fuel cycle to be adopted, regulatory requirements, etc., but in relation to the first nuclear power plant it is most often the electricity generating authority or utility which takes the initiative as it is they who decide when a big thermal station is needed and, therefore, when a nuclear project should be considered as an alternative to an oil-fired station. The cooperation of other organizations must, however, be assured, for instance, through the creation of a committee for nuclear power, charged with formulating a detailed programme of action. Such a committee should have representatives of the utility or utilities and of the interested government departments. In particular the Atomic Energy Commission or Authority, the Planning Commission, the Power Commission or corresponding organizations and those departments which are responsible for environmental protection should also be represented. The representatives should be at the executive level to ensure not only that the committee will be able to formulate a realistic and viable programme but also that all departments and organizations concerned are aware of it.

If a nuclear research centre, possibly with a research reactor, exists in the country, it will be possible to draw on it for some of the experienced nuclear scientists and engineers who will be needed both at this first stage and later in the realization of a nuclear power programme. A research reactor, though useful for some training, is, however, not necessarily needed in order to launch a nuclear power programme.

As for other potentially hazardous activities it will be necessary for the national authorities to enact legislative and regulatory provisions for the control of the uses of nuclear energy, as well as any uses of radioactive substances in medicine and industry. It is also equally important that the regulatory function is separate from that of constructing and operating nuclear facilities. This will require the setting up of a legal framework, the preparation of regulations and the establishment of a regulatory authority. In view of the time it normally takes to enact legislation and set up new organizations, this work should start at as early a stage as possible.

During the early stage one of the most serious difficulties for the planning work is normally a lack of qualified staff who can advise the executive level and provide the background information needed for decisions. In some cases ministries or generating authorities have consulting engineering firms available on a more or less permanent basis. In other cases consultants are called in to advise on specific aspects. In the first phases of planning the interministerial character of the work to be done and the type of advice needed may, however, limit the usefulness of consulting engineers. What is needed at this stage is advice on an early formation level and that can often be better provided by an intergovernmental organization such as the IAEA.

1.6. The IAEA and its advisory services

The International Atomic Energy Agency (IAEA) is an autonomous intergovernmental organization with headquarters in Vienna, Austria. It is related to the United Nations by an agreement which recognizes it as the Agency under the aegis of the United Nations responsible for international activities concerned with the peaceful uses of atomic energy. It has more than a hundred Member States and it provides assistance to developing countries among them, both through a technical assistance programme and through advisory services.

(a) The nuclear power planning study

In the early stages of a nuclear power programme the IAEA can be of assistance in reviewing the power situation in the country, in advising on the utilization of resources and the power system expansion, including consideration of nuclear power, advising on the legislative and regulatory framework needed, and informing, as required, the utility and a committee for nuclear power on various aspects of nuclear power stations[1.4]. IAEA staff members are available to carry out studies, to collect information for evaluation and to give advice on these subjects. The IAEA can perform a nuclear power planning study for a country upon request. The nuclear power planning studies generally have as objective:

- To review the electricity generating and distribution system in order to advise on the possible sizes of nuclear plants that should be considered for economic competitiveness and the time when they could be introduced in the electric grid;
- To review the present organizational structure and advise on future organization and requirements for trained manpower; and
- To review the possible general area locations of nuclear power plant based on technical considerations.

[1.4] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Services and Assistance, IAEA, Vienna (1973).

The evaluation uses a methodology that was developed in the Agency's market survey for nuclear power in developing countries in 1972-73 and which uses an overall system expansion optimization approach to determine optimum sizes and timings for all plant additions taking into account load characteristics and system stability and reliability. This is done with the help of a series of computer programmes which are available to Member States of IAEA upon request. Training in their use is also provided at IAEA.

A nuclear power planning study performed by IAEA usually requires a mission by Agency staff members, spending about two weeks in a country to collect the information needed. The only costs involved for the country are those for per diem and local transportation, and as a mission usually consists of 3-4 members the total cost is normally less than US $1200. It is thus an inexpensive way to get an impartial review of expansion plans and organization and it is a benefit of IAEA membership which is easy to utilize.

IAEA intends to issue a detailed manual on the methodology and procedures to be used in a nuclear power planning study in order to facilitate for Member States to perform these studies. Whether the Agency is called to perform it or the authorities decide to perform it by themselves, the nuclear power planning study is a fundamentally important first step to show the need for and the timing of a future nuclear power programme.

(b) Advice on safety matters

In the early stages of a nuclear power programme, the IAEA can be of assistance in all the problems through missions of experts which may give advice:

- On the setting up and organization of the regulatory authorities and training of the staff which will be in charge of the analysis of the safety aspects of the site and of the station;
- On a first preliminary survey of suitable sites which will permit selection of the ones more suited for more detailed evaluation;
- On the approval of the selected site;
- On how safety problems should be taken into account in the contract;
- On the safety evaluation of the design and on the construction permit;
- On surveying the design and construction work;
- On the operation permit;
- On the assessment of operating personnel qualifications;
- On management of radioactive wastes;
- On evaluation of environmental aspects and on related monitoring; and
- On operational radiation protection problems.

2. PREPARING FOR THE FIRST NUCLEAR POWER PROJECT

Assuming that the nuclear power planning study has indicated that a nuclear power programme would merit further consideration, the immediate problem is to estimate the time and to establish the staff required for preparing such a programme. Very often both these have been underestimated in the past and the following will highlight the basic requirements and the particular aspects of nuclear power projects, the typical time requirements and the resulting staff needs.

2.1. The special features of nuclear plant

(a) High initial capital investment[2.1]

A nuclear power plant typically requires about twice the initial capital investment of a fossil-fired plant of the same size. For the USA and Western Europe the capital cost of an 800 MW(e) unit is now in the range of US $480/kW corresponding to a total investment of US $380 million. In developing countries the initial capital costs over several projects should be somewhat lower due to the lower wages of the labour needed for construction and installation work. This has been the case for oil-fired thermal power stations in the past. Taking into account lower labour indices, an indicative initial cost for a 600 MW(e) would still be at least US $410/kW, i.e. a total capital investment of US $250 million. This is, however, unlikely to be the cost for a first nuclear power plant which would presumably have many first-of-a-kind costs for staff, outside help, turnkey contract etc.

The economies of scale are even more important for nuclear power than for fossil-fired stations. Figure 2.1 gives some data for initial capital costs for kW installed capacity of power stations in developing countries derived during up-dating of the nuclear power market survey which the IAEA conducted in 14 developing countries in 1972-73. It should be noted that these costs are total estimated costs and include indirect costs for management services and interest during construction. The direct costs for the purchase contract may be considerably smaller as, for example, only interest during construction can be some 20% of the total cost.

The very high capital cost is in operating economics offset by very low fuel costs but this will also mean that the plant should be operated at full capacity to the extent possible. A forced plant shutdown during one day for a 600 MW nuclear plant will mean a loss of revenue of at least some US $150 000 with a saving in fuel during that day of only some US $25 000. The power not produced by the nuclear plant will, furthermore, have to be provided — more expensively — in some other way. This stresses the importance of achieving the highest possible degree of reliability in a nuclear plant. This requires the choice of a proven reactor system, that is, one which has been demonstrated somewhere else to be reliable during operation (in practice interpreted to mean that both reactor and turbo-generator systems have been in satisfactory commercial operation with better than 75% availability for not less than one year), and which has been reviewed from the safety point of view and been given an operating permit in another country. This, at the present time in 1974, would limit the choice of

---

[2.1] All cost data are given in January 1974 US $.

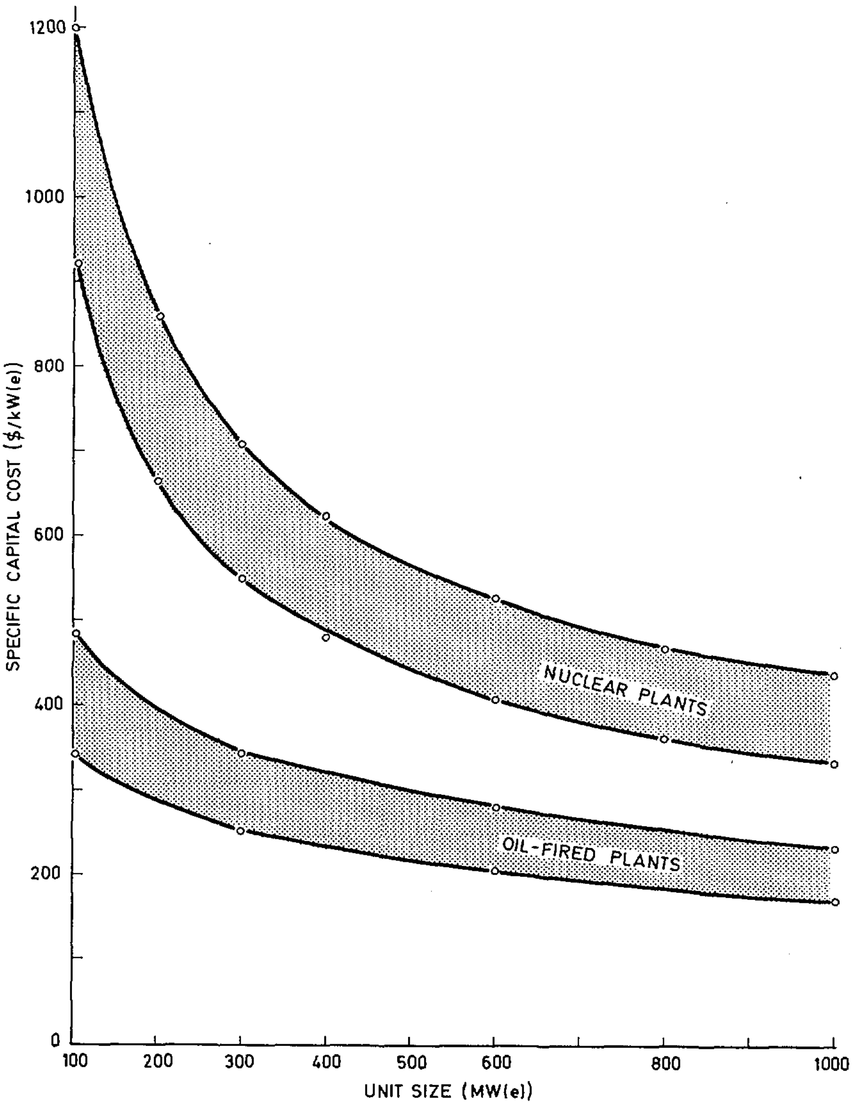


FIG. 2.1. Capital costs of nuclear and oil-fired power plants in developing countries in units of US $ of Jan. 1974 (estimated).

commercially available reactor systems to light water reactors of pressurized or boiling water type or heavy water reactors of the pressure tube type. It can be expected that the high-temperature gas cooled reactor will have achieved proven status within the next few years (see also Section 4.5).

The vendor of the plant which is selected must also have demonstrated experience in the design, supply, construction and start-up of nuclear units of at least the same size (see also Section 4.7).

It is to be expected that international financing institutions will have very strict requirements for demonstrated provenness and safety before accepting to contribute to the financing of nuclear power stations, and correspondingly these aspects must be given careful consideration in reactor type selection and bid invitations.

Due to the high initial costs and the consequent high costs of outages, it will be necessary for the buyer of a nuclear power station to institute organizational and administrative measures from the very beginning of work on the project to assure not only provenness but also that extremely strict specifications are laid down – and followed – for the very highest quality in design construction, installation and operation, that is, a quality assurance programme will have to be established by the buyer in a manner which is not usual for a conventional power station (Sections 4.1 and 6.4).

The capital cost per kW installed of a nuclear plant decreases substantially with the size of the plant (Fig.2.1) and proven nuclear plants are furthermore now commercially available only in sizes above 400 - 600 MW. With the present oil prices this will be a strong incentive for introducing a big power station even in a small electric system at an early date. A sudden outage of a big power unit can cause severe problems of stability of the whole electricity supply system. Normally, it is not advisable to install units of more than 15-20% of the system's peak demand but economical benefits from a big nuclear power plant may make it desirable to review the policy of reliability of power supply and, e.g. shed unimportant loads in case of a sudden plant outage, or even operate a big unit at less than full power for an initial period of time. These are problems which should be given consideration in the nuclear power planning study.

(b) Safety requirements

Because of the radioactivity produced in the reactor core, there are potential hazards to the public and the environment, both from normal radioactivity releases from routine operation and from releases which could result from accidents with the reactor. In the present public debate these risks have often been greatly exaggerated and the fact remains, that at the end of 1972, 1004 reactor years of operating experience with civilian power reactors had been accumulated in the world without a single accident involving accidental release of harmful amounts of radioactivity to the surroundings. It is still necessary for a Government to make provisions within a special legal framework with two main objectives:

- To set out principles and criteria for prior authorization and control of nuclear installations, establishing a competent regulatory authority with appropriate powers for this purpose;
- To lay down principles to govern nuclear liability and conditions under which compensation for nuclear damage is to be provided.

The establishment of legal provisions for third party liability protection is usually a prerequisite for the international supply of reactors, components and nuclear fuel. Standards for such protection are given by various international conventions (see Annex 2) which provide for:

- The channelling of liability to the operator of a nuclear installation, whose liability is absolute, irrespective of fault;
- A limitation in amount and time of the operator's liability; and
- A single competent court and one law applicable to all claims resulting from a nuclear accident.

This means a much stricter liability situation for the owner of a nuclear plant than for the owner of a conventional power station. As a consequence, the owner of a nuclear plant in most countries will have to obtain permits from a regulatory body for siting, construction or operation of a plant.

The procedures which are to be followed in order to put a power plant in operation are in many countries the following:

After the presentation to the regulatory authority of a site report in which all the safety characteristics of the site are evaluated, including the environmental aspects, normally a preliminary and conditional statement on the suitability of the site for a well-proven reactor is given by the regulatory authority.

Upon the presentation of the complete preliminary safety analysis report in which all the safety aspects of the site and of the plant are presented and proof is given that all the relevant safety problems have been taken into account, a construction permit is issued, sometimes on condition that particular requirements will be fulfilled.

Later and towards the end of the construction period, the final safety analysis report is presented. In this report, the solutions of the safety problems are given and the fulfillment of the construction permit requirements is demonstrated.

In a separate report the results of pre-operational tests, performed without fuel in the reactor, are presented. It must also be demonstrated that an emergency plan has been set up and that the operators have received all the required training and that third party liability coverage exists. In certain countries, the operators have to be licensed. On these conditions an operating permit may be issued so that fuel can be charged into the vessel and the reactor can be brought to first criticality and operated within specific limits and conditions.

Afterwards, during the life of the plant, the regulatory authority will ascertain through inspections that the safety standards of the operation are high and that the safety characteristics of the plant are well maintained.

The owner and operator of a nuclear power plant will thus have to accept a much stricter responsibility both for the continued safety and the long-term reliability of the plant than for a conventional plant. He will have to commit himself to a policy ensuring very high quality for all the stages of a nuclear power plant project and he will be subject to reviews and inspections by a regulatory body. All this will call for additional qualified staff both on the owner's project staff and the regulatory organization, at an earlier stage than would have been the case for a conventional power station project.

(c) The long-term commitment

The decision on a first nuclear power plant should always be taken against the background of a continuing long-term nuclear power programme involving the possibility of a number of nuclear power stations over a period of 10 - 15 years. The IAEA nuclear power planning studies should give an indication of the scope and timing of such a programme. It is towards the long-term nuclear power programme that the staffing and training programmes should be directed even if they have to be focussed first to meet the more immediate demands of the first project.

(d) International agreements for supply

The selection of a particular reactor system for the first project should also be regarded as involving a possible long-term commitment to a specific type of fuel cycle with concomitant limitations in the choice of future suppliers. Each major reactor type has specific requirements for fuel and fuel cycle services. Of the presently commercially available proven reactor types, i.e. light water reactors (LWRs) and heavy water reactors (HWRs), HWRs can operate on natural uranium fuel and indigenous uranium resources could make a country independent of outside fuel suppliers in the long term if this reactor type is chosen. Nuclear fuel manufacturing is, however, a very complex industrial process with extremely high quality requirements, the difficulties of which should not be underestimated. The nuclear power programme must also have a considerable size before the fuel requirements are so big that a fuel manufacturing plant is economical. Furthermore, even if fuel can be produced domestically, a long-term dependence on foreign reactor plant vendors is still very likely.

LWRs have a more complex fuel cycle (Fig.2.2) and require uranium, enriched in the isotope U_{235}, as fuel and there are at the present time only five possible sources of supply for enrichment in the world. Likewise, there are only a limited number of fabrication and reprocessing plants or plutonium storage facilities. The whole question of supply of fuel and fuel cycle services is extremely complex and this manual will not deal with these problems as it is planned to issue a separate IAEA manual on this subject in 1975. It should, however, be pointed out that contracting for fuel supply and services requires very early preparations. The lead times required for enrichment services for a first reactor core may actually be longer than the construction time (8 years compared to some 6 years).

In this context it is worth remembering that the IAEA's statute provides for it to act as a supplier of fuel material and fuel cycle services, e.g. enrichment, either directly or as an intermediary. This broker rôle of the IAEA is explained in more detail in Annex 3.

The nuclear power plants themselves are, of course, also extremely complex and require specialized and highly experienced manufacturing facilities, which again can only be provided by a very limited number of suppliers. At the present time only six companies or authorities in five countries have had export orders for proven, commercial nuclear power plants of the LWR or HWR type.

These present strict limitations in the number of possible suppliers for plants and fuel must be carefully considered together with the industrial

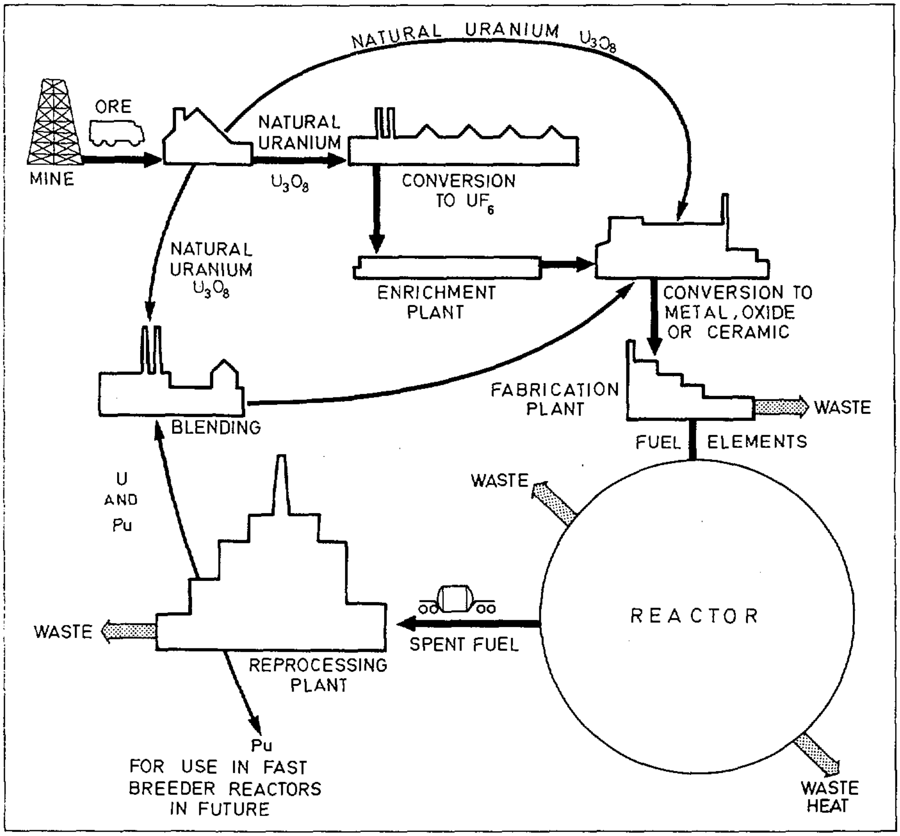


FIG.2.2. The nuclear fuel cycle.

potential and development plans in the choice of the first reactor type because of the long-term implications that it may have both for the first plant itself and its future fuel supply, and for future plants.

(e) International safeguards

Nowadays, most of the major supplier nations of nuclear fuel, reactors and components, and equipment require that the IAEA should apply its safeguards to ensure that the fuel, the plant or any of the equipment are not used to make any kind of nuclear explosive device. If the purchasing nation is a party to the Treaty on the Non-Proliferation of Nuclear Weapons, the nuclear material in the country becomes subject to Agency safeguards pursuant to an agreement which the State should conclude with the Agency as required by the Treaty. [The IAEA document INFCIRC/153 contains the substance of such agreement.] If the purchasing State is not a party to the Treaty and does not have any agreement with the Agency for the application of safeguards, it will have to conclude such a safeguards agreement with the Agency in connection with the supplied nuclear materials, reactors and equipment. Being a prerequisite for the supply, the need for concluding such arrangements with the Agency should receive early attention.

The basic objective of IAEA safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities and the deterrence of such diversion by the risk of early detection. To achieve this objective the Agency verifies materials accounts through inspections. Containment and surveillance of material can be used to complement materials accounting.

The plant operator must keep records on the materials in his possession. Accounting reports for the fuel in the installation based on these records must be sent periodically to the Agency in Vienna. From time to time Agency inspectors will verify these reports on the spot and look at the records kept by the reactor operator with respect to the nuclear fuel. The frequency and length of the inspection varies according to the nature of the installation. For a power reactor relatively few days are required. The details of the safeguards procedures, including sample accounting forms and the specification of the places in the installation to which the Agency's inspectors would normally have access, are laid down in "Subsidiary Arrangements" between the State and the Agency. [Models of such Subsidiary Arrangements can be supplied by the Agency when needed.] In preparing the Subsidiary Arrangements the Agency examines information on the design of the plant which should be provided by the State on the basis of a "Design Information Questionnaire" [of which copies can be obtained from the Agency]. The design information to be provided is limited only to those items that are of direct importance to the application of Agency safeguards.

Normally the State will wish to set up its own system of accounting for and control of nuclear material. Strict accounting is required for reasons of both safety and economy. The safeguards agreements also require that the State should establish its own system of accounting for and control of nuclear material. Usually the State will wish to establish a central authority which is responsible for the transmission of safeguards accounting reports from the various installations and which provides the staff that accompany Agency inspectors during their inspections. This body would provide the primary working level contact with the Agency on the subject of safeguards.

The government would also wish to provide for physical protection of nuclear material against theft, sabotage, etc. The Agency has published recommendations for such measures (Recommendations for the Physical Protection of Nuclear Material, IAEA, Vienna (1972)).

(f) Requirements for manpower and skills

As has been pointed out repeatedly above, a nuclear power project will involve much stricter requirements for quality control and quality assurance than would apply for a conventional project and it places the buying utility or power generating authority in a position of much stricter responsibility in relation to both the local government authorities and the public. The construction and operation of a nuclear plant requires more than a simple extrapolation of conventional skills in power plant technology. There are

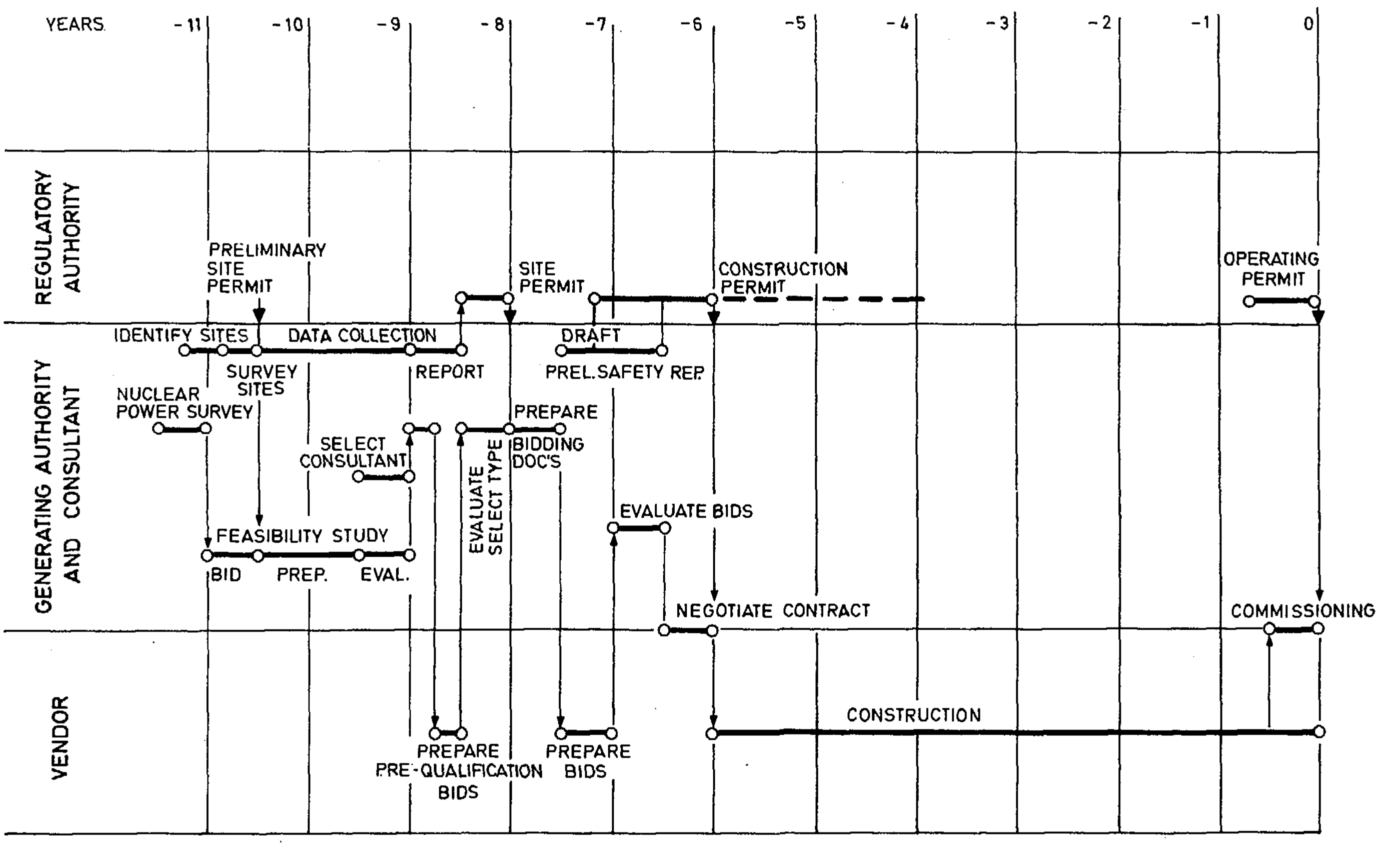


FIG.2.3. Approximate overall time schedule for a first nuclear power plant project.

also definite requirements for technical support from other branches, e.g. for transportation of heavy equipment, site data collection and communications. The questions of supply and financing are also much more complex than for conventional power stations. Thus attention must be given very early to the establishment and training of highly competent staff both in the future project organization and in the regulatory authorities which will have to review the project. For the buyer it will involve, even in the simplest case, a much higher manpower requirement at an early stage and recruitment of this staff is likely to present severe problems. In addition, professional assistance from consulting firms will have to be called in early for a variety of tasks, ranging from siting, feasibility studies, preparation of specifications for bids, bid evaluation and construction supervision.

On the other hand, the first nuclear power project can, if properly planned, give very valuable "spin-off" for a country's general industrial development. It will require technical and labour skills of high quality in several areas, e.g. construction, welding and electrical installation, and can give a substantial contribution to the creation of a skilled labour force in these areas. Any local industries, participating in the project, will have to work to specifications which are likely to be much stricter than they have experienced before and a nuclear project can in this way help to increase industrial quality. It is, however, essential for success to evaluate the possibilities for local industrial participation carefully and realistically from the very beginning.

Under all circumstances, it is of greatest importance that the demands which will be placed on the management by the magnitude and complexity of a first nuclear power project, are not underestimated in the early stages and that provisions are made for adequate staffing and financing of a technical group from the very beginning.

2.2. The overall time schedule for a first nuclear project

Experience indicates that the first nuclear power projects in a country outside the major nuclear powers have required on the average just over five years from start of construction to commercial operation. (The actual values in nine countries range between a minimum of four years and a maximum of 6.5 years.) The construction times have during the last couple of years shown an increasing trend partly because of licensing delays but also due to increasing delivery times for key components. To the construction time proper must also be added a time of between half and one year after a contract has been signed until construction at the site can start. In all, it is at the present time realistic to count with a time of at least about six years from the signature of the contract with the reactor plant vendor until a plant of some 600 MW(e) can be expected to be in commercial operation. For a conventional plant in the same size the corresponding time is likely to be some four years.

However, the six years of construction time represent only a part of the total time needed to prepare for a first nuclear power project. An approximative overall time schedule is given in Fig.2.3. It is, of course, only representative of one possible approach and may not even be typical.

However, it is important to recognize in this time schedule some of the preparatory activities which have to be performed, and the times which have to be allotted to them:

(a) After a nuclear power planning study has indicated that it would be timely to embark upon more detailed studies, a pre-investment or feasibility study (Section 3) should be performed by a reputable firm of consultants. Including the bidding process to select the consultants and a period to evaluate the results of the study, experience has shown that this will require a total time of about two years. During the early part of this period one or two definite sites for the power station should be selected so that the feasibility study can be made, based on the conditions prevailing at the actual site.

(b) The overall time schedule also allots one year for pre-qualification bids (Section 4.7) to select a smaller number of reactor plant suppliers which would participate in the final bidding for the project. This step has often been omitted in past projects but it is very desirable to include it. It will not only give a good idea of the interest, capabilities and experience of the main manufacturers and their subcontractors, but it should also give definite information about the types and sizes of power plants which can be supplied and the scope of the supply. In this way the best possible information is available at the time when the decision about the reactor type and fuel cycle should be taken. Furthermore, the pre-qualification bids will assist in the preparation of the final bid documents and help to assume to the extent possible that the final bids by the potential suppliers are comparable. Thus, the time spent on a pre-qualification bid round is valuable and may save time in the final bid round and it is recommended that it should be seriously considered.

(c) For the final bid round (Section 5) a period of two years has been allotted including preparation of bid documents, bid evaluation and negotiation of the contract. This time is realistic, as experience has shown, but may possibly be shortened by about half a year under favourable conditions. During this time, at the latest, arrangements will also have to be made for fuel supply.

If completely standardized power plants were available and chosen for the bidding process, it might help to shorten the whole time period by 2.5 years (0.5 year in the feasibility study, 1 year as pre-qualification bids would not be necessary and possibly 1 year in the bidding round). Even so, the overall time schedule would be shortened to only about 8.5 years instead of 11 years. This again stresses the need for early planning and for adequate staffing of the project group at an early stage.

The time schedule outlined above with the possible shortening to some 8.5 years can be used to achieve an orderly build-up of the organizational structures which are needed and to take the required decisions when needed and on a full information basis. With the present high oil prices it must, however, be recognized that if an oil-fired plant has to be installed because of delays in procurement of a nuclear plant it will lead to extra costs which for a 600 MW thermal plant will be of the order of several $10 million. It may thus be necessary for energy policy reasons to shorten the overall time schedule, but even with ready financing, a chosen site, quickest possible licensing procedures, and site data collection going on in parallel with the bid evaluation it seems practically impossible to shorten the total time schedule to less than seven years after a firm decision on the construction of a nuclear plant has been taken.

2.3. Organization and manpower requirements

If a nuclear power planning study has indicated that work should be started towards the first nuclear power project, it will be necessary to start staffing both the regulatory authority and the project group which will be involved in the selection of a site and a feasibility study. At this time, it would also be desirable to start surveying the local industry in order to assess the possibilities for local participation in any phases of the construction of the plant.

It is, of course, necessary to begin the staffing bearing in mind the final requirements for a regulatory body which will be able to review and assess the safety of the plant and later inspect it for compliance, and a project group which will be able to specify to potential suppliers the plant wanted and exercise competent surveillance of manufacture and construction. For this purpose Figs 2.4-2.7 show typical organization charts for a regulatory authority, the project group and the operations group as they may be set up when fully staffed. It is recognized that at the beginning probably only a skeleton staff will be recruited depending entirely upon some other organization for administrative and other supporting services.

(a) Regulatory authority

The IAEA has published a Code of Practice for the Safe Operation of Nuclear Power Plants (Safety Series No.31, IAEA, Vienna (1969)) in which it is stated that: "In discharging its responsibility for public health and safety the Government should ensure that the operational safety of a nuclear reactor is subject to surveillance by a regulatory body, independent of the operating organization."

The IAEA has also published guidelines for the Organization of Regulatory Activities for Nuclear Reactors (Technical Reports Series No.153, IAEA, Vienna (1974)) which provide detailed guidance for the establishment and organization of a regulatory authority. It is thus enough to stress in this context the necessity to have, already at the time of the first steps towards a feasibility study, at least a skeleton staff with enough competence in nuclear safety and siting (including knowledge in areas of meteorology, ecology, geology, hydrology, seismology and soil mechanics) to review site proposals and give at least a preliminary approval of a specific site subject to confirmation when enough data have been collected. At this stage, assistance by the IAEA in performing a site survey can be of great importance. It is an advisory service which is available to Member States at very low cost.

(b) Project organization

For a nuclear power programme it can be expected that a department of the ministry, generating authority or utility, or even a separate authority will finally be set up for administration and execution of the series of individual projects. The example of a project group shown in Fig.2.6 is one which could be suitable for the first project only and would have to rely on the administrative services, such as personnel and treasury departments, of the ministry or other authority. For the initiation of the site selection

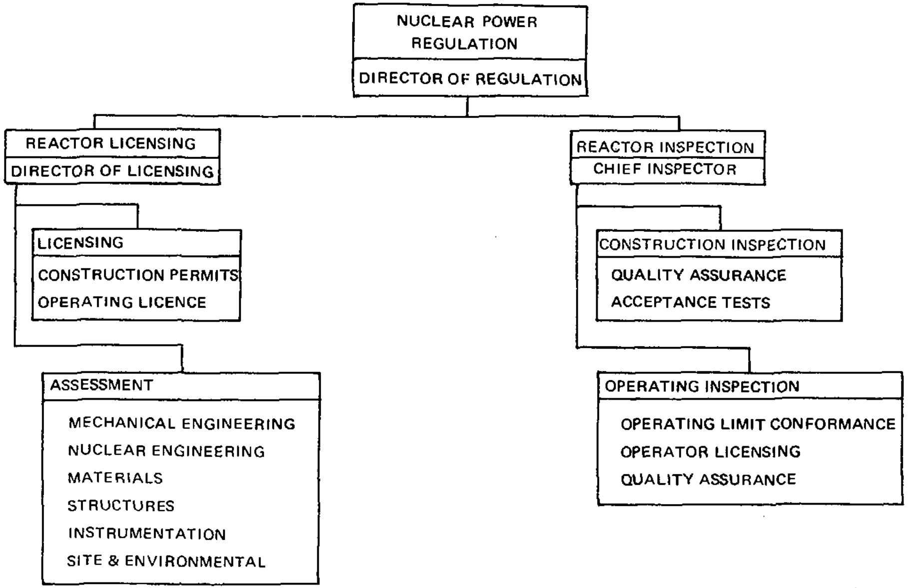


FIG.2.4. Example of organization of regulatory body.

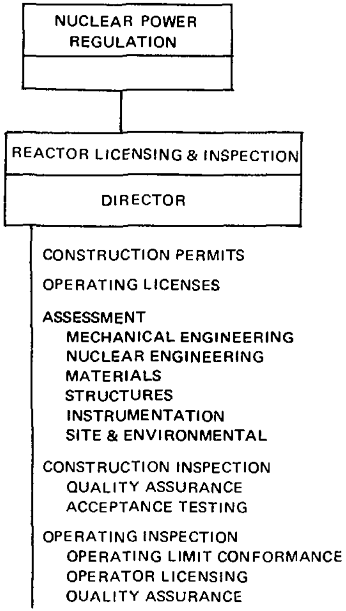
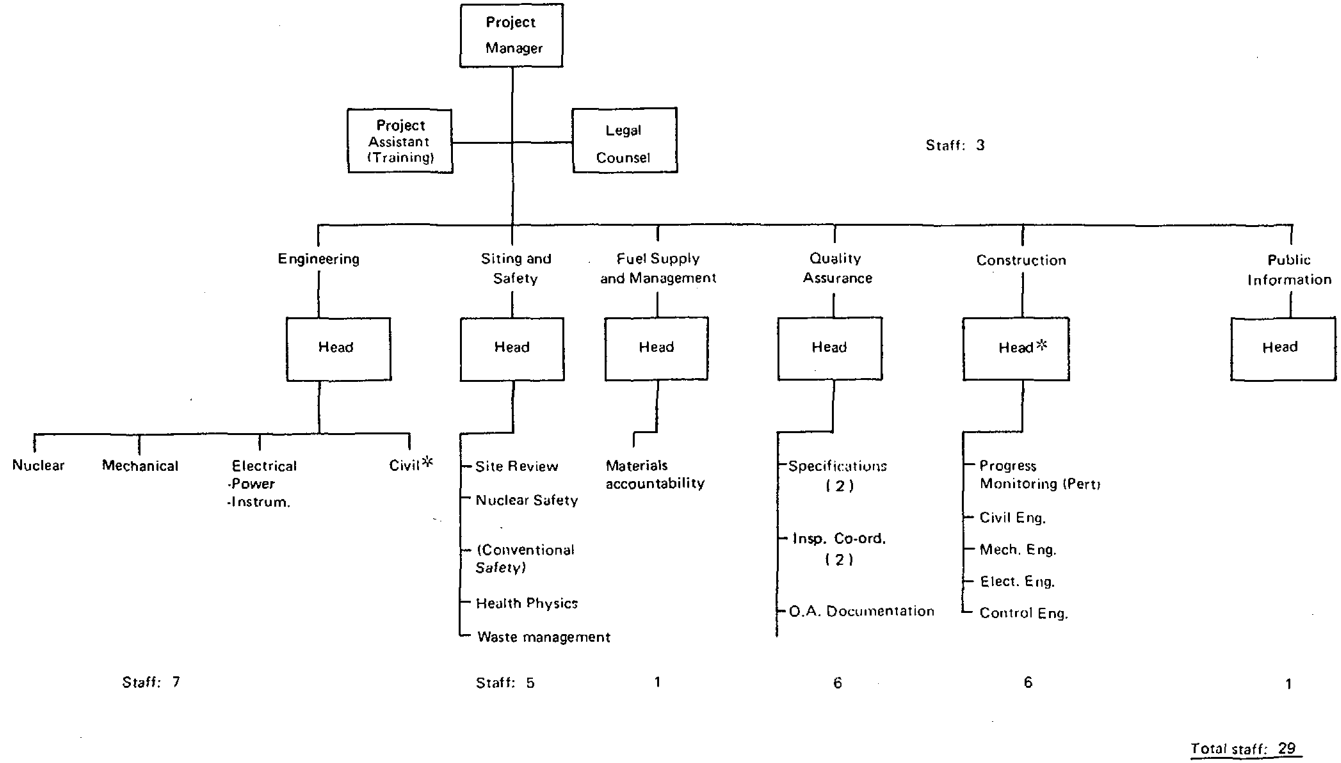
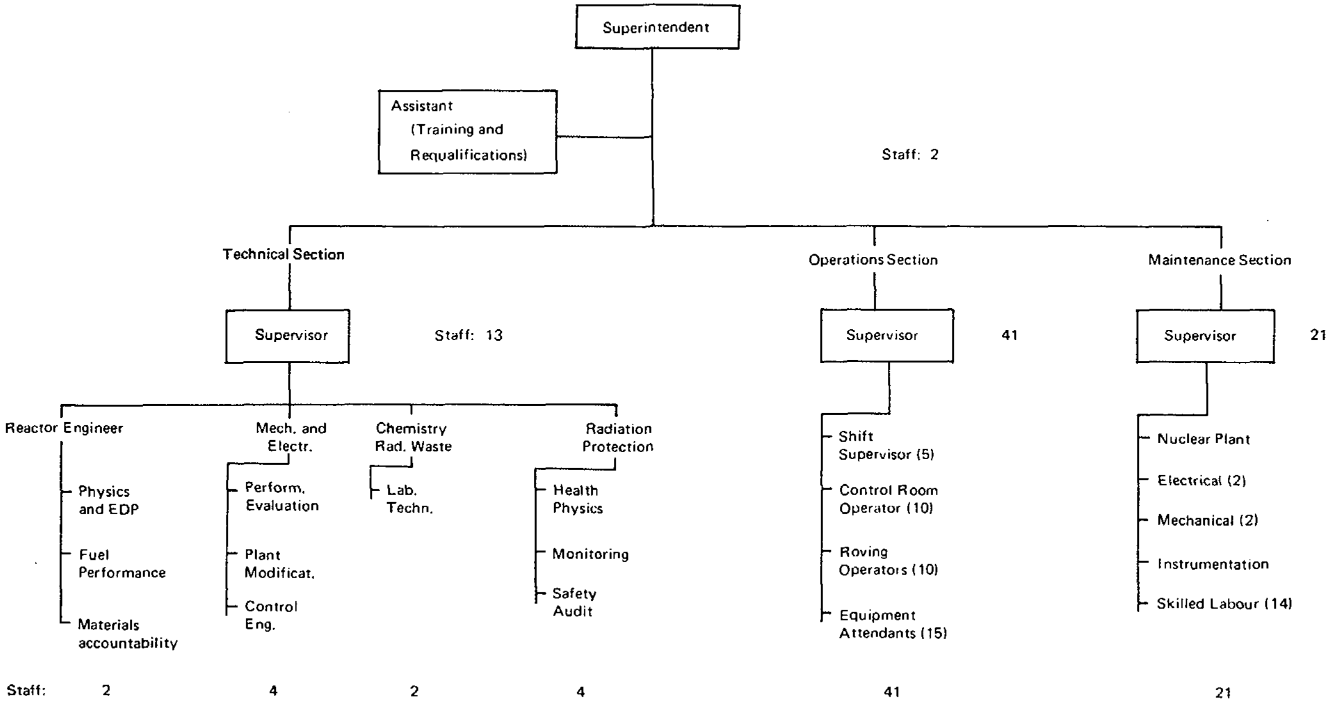


FIG.2.5. Simple organization of regulatory body.



* Could be same person.

FIG.2.6. Example 1: Project Group Organization.



Staff: Professional and Technical 63
Other 14
Total 77

FIG.2.7. Example 1: Operations Group Organization.

and feasibility study it is strongly recommended that a staff of at least 6 - 8 qualified engineers should be assigned to the project group in order to cover at least the following functions:

- Project management office including the training function which is of extreme importance all through the project (2 staff)
- Engineering support in nuclear, electrical, mechanical and civil engineering (2 - 4 staff)
- Nuclear safety and siting (1 staff)
- Public relations (1 staff)

It is to be noted that a full-time staff member is proposed for the public information function already from the beginning of site selection (compare Section 2.5).

Table 2.1. gives a possible recruitment schedule and Annex 4 gives an example of possible qualifications and experience that should be required when recruiting staff for the project and operations groups. The examples are, of course, schematic and should be used for guidance only. One important aspect is, however, that the project group to be established should not consist of nuclear specialists but rather of senior and experienced conventional power project engineers supplemented by a few nuclear experts. It will be necessary to give these engineers additional training in nuclear power engineering both through courses and in on-the-job training assignments at nuclear power projects in other countries. At the present time, it is difficult to find opportunity for these types of training, but the IAEA is making a special effort to provide for project oriented training of this type, within an expanded training course and fellowship programme, starting possibly from 1975.

When planning the training of those engineers who will become part of the project engineering group, it is necessary to keep clearly in mind the function of the project group, which will be to take responsibility for the nuclear power station project from the early decision making and planning stages until the power station is complete and in operation. Research is not an important activity of the project group, nor is basic reactor design. The nuclear power station project will utilize existing nuclear technology and tested reactor design. The training of the project group must concentrate on existing nuclear technology and construction standards.

If the engineers chosen to become part of the project group have already had experience in large-scale engineering projects such as thermal power stations and refineries, their training need concentrate only on those areas related to nuclear power stations. Fundamental training in nuclear reactors and nuclear engineering may be necessary, along with training in electric power systems, nuclear fuel management, economics of nuclear and thermal power systems, contract preparation and bid evaluation, construction scheduling, quality assurance methods, regulation and licensing, site selection and preparation, etc. Training should emphasize familiarization with existing nuclear power station equipment, construction procedures, and methods of quality assurance.

Figure 2.7 gives an outline of an operations group organization. This only represents the technical and skilled labour staff requirements. If non-technical staff (office staff, nurses, guards, etc.) are included the total staff is likely to be some 120 - 130 people. More important is that the figure does not include the total labour force which may be needed for major and most

TABLE 2.1. POSSIBLE RECRUITMENT SCHEDULE FOR PROJECT STAFF: PROFESSIONALS AND TECHNICIANS (Turnkey project, maximum delegation to consultants)

Year	-11 Siting; feasibility study	-9 Safety report; bid preparation and evaluation; contract negotiation, fuel contracts	-6 Construction	-1 Commissioning	0 Routine operation
Project Organization					
Project manager's office	2	3	3	3	3
Engineering section	4	7	7	7	7
Siting and safety section	1	3	4	5	5
Fuel supply and management section	0	1	1	1	1
Quality assurance section	0	3	6	6	6
Construction section	0	1	6	6	6
Public information section	1	1	1	1	1
TOTAL	8	19	28	29	29
Operations Organization					
Superintendent's office	0	1	2	2	2
Technical section	0	1	5	13	13
Operations section	0	0	-5 : 1 -4-3 : 41 (training)	41	41
Maintenance section	0	0	5	7	7
TOTAL	0	2	12 - 54	63	63

often unforeseeable maintenance work for which it may become necessary to have a back-up group of up to 100 people. With several plants in operation it will be possible to provide for such a group which travels between the plants but for the first plants it will be a major problem to be prepared for extensive maintenance and repair work. It is generally not advisable to overstaff in order to meet unforeseeable situations, but in the case of a nuclear power organization, in view of the opportunities which it gives for advanced training, it may be possible to have a very large maintenance group which is also given other tasks of maintenance outside the power industry. In this way it could be possible to guarantee that a large group is available if and when it is needed.

The training of most of the technical staff in the operations group is likely to be less of a problem than for the project group as the reactor plant vendor normally would supply this training at simulator centres and plants which he has supplied earlier. For the senior and earliest recruited staff it will be necessary to use the same training as for the project staff.

2.4. Site selection

One might gain the impression that there is a considerable discrepancy at the present time between siting practices in many countries. However, the sites now being used, for instance in the United States, are not very different from those used in Europe. Moreover, in the discussions by various siting experts there is a firm measure of agreement on some of the important factors in siting of nuclear power plants. This very brief discussion will concentrate on the generally agreed aspects of nuclear power plant siting.

There are three basic considerations that have to be taken into account for site evaluation. They are:

Characteristics of the reactor design;
Population density; and
Physical characteristics of the site.

(a) Reactor design

Considerations should here include the proposed use and maximum power level of the reactor and also the extent to which generally accepted engineering standards are to be used in its design and construction, and engineering safeguards proposed to reduce the likelihood and consequences of reactor accidents.

At the siting stage for most nuclear power plant proposals the reactor design is, however, not known, except for some general data. One will know only, that the plant should be of a certain power and be used for power generation. One should further be able to assume that it will be of a well proven design and be based on some reference plant, also licensed or under construction in the country from which the reactor has been bought.

(b) Population density

It is not possible to give internationally acceptable criteria for permissible population densities around a nuclear power plant, but some simple examples may give indications. It is necessary to know the amount of land

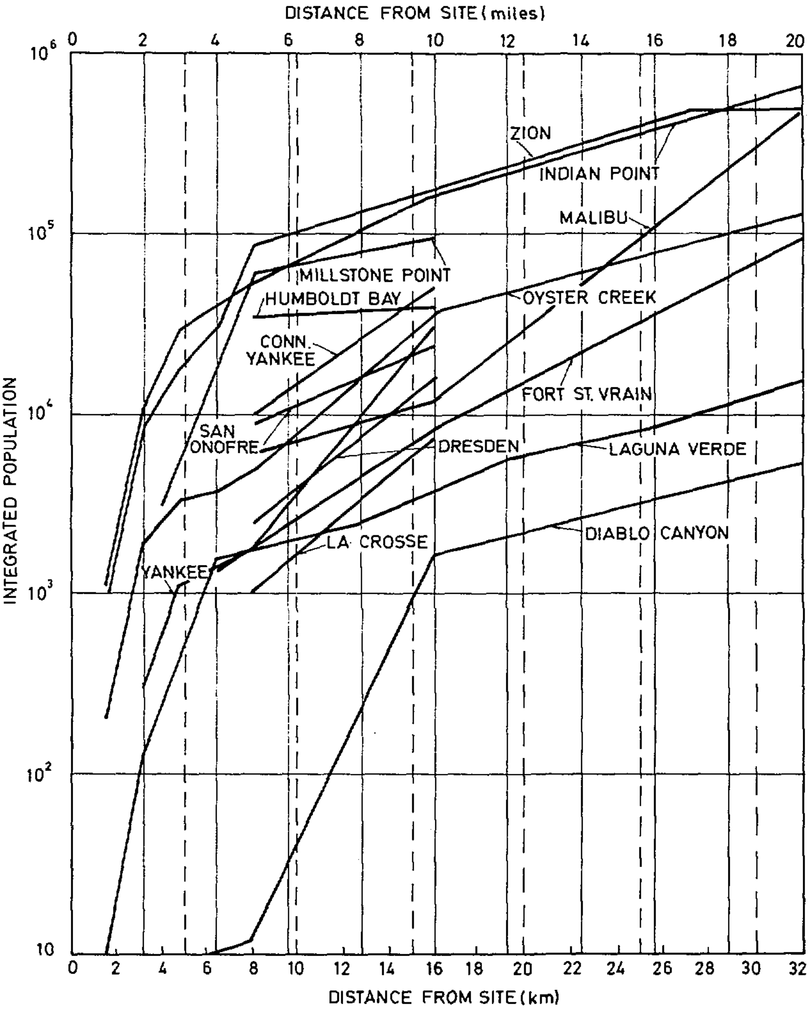


FIG. 2. 8. Examples of integrated population as a function of distance from some power plant sites in the US.

under the control of the reactor owner, distances to the site boundary and densely populated centres, and densities of population between the reactor site and the population centres. Figure 2.8 gives a few examples of the radially integrated population as a function of distance from the site for various nuclear power plants. Agency siting missions have used this figure as reference curves. If for any specific case the corresponding curve would be lying more or less central to these curves, then with some justification the population distribution could be regarded as fairly normal and the normally incorporated features of engineering safeguards would be adequate. On the other hand, if the curve lay below the described curves, then the population problem could be regarded as minimal. If, however, the curve lay between the upper level or above the curves, then this would be an indication of a serious population density problem for the site which might even rule out the site altogether on safety grounds.

(c) Physical characteristics of the site

The main factors to be evaluated are:

Ground and site preparation

Circulating water system

Plant foundation

Site accessibility and power transmission.

These factors would apply to any thermal power plant. In addition, one would wish to know details regarding topography, geology, flooding, meteorology, tsunamis, seismology, and air and ground hazards which might be applicable.

Ground and site preparation

An area of 40 - 80 hectares is normally needed for a nuclear power plant and building structures will cover a surface of about 2.5 hectares.

Circulating water system

An adequate and unfailing supply of cold water is required for cooling. The amount depends on the station but a typical value for a light water cooled 600 MW capacity station would be 18 - 25 m^3/s. This supply must be unaffected by tidal or water conditions with an intake which is always at sufficient depth to avoid vortices and air entrainment. Cooling water tunnels for these quantities of water are expensive and deep water close inshore is an advantage.

If wet cooling towers have to be used, this will require a water consumption through evaporation which for a 600 MW plant would be about 0.6 m^3/s. Increased capital costs would be incurred at sites that require long channels or offshore pipes to reach water at sufficient depth or provide recirculation of the warm water. Extra operating costs would be associated with extra pumping head for sites requiring long inshore pipes or extra elevation above the water supply surface. Should the site have large wave hazards, perhaps associated with tsunamis or ocean waves, extra elevation would be needed and in this case additional operation costs would be the result.

Plant foundation

Thermal plants require foundations that must be capable of supporting quite large loads but generally speaking, most sites are adequate. For a

500 MW nuclear unit, the foundation loads will be about 40 tons/m^2 for the nuclear area and 15 tons/m^2 in the turbine area. The plant auxiliary areas will require normal foundation loading.

Site accessibility and power transmission

The movement of construction personnel, fuel materials and waste to and from the site entails large costs which can differ materially from site to site. The variance in plant capital costs due to transport costs can be several millions of dollars. Highway access for personnel and material delivery and water access for heavy material is, of course, desirable. Transmission costs are a direct function of the distance from the plant to the nearest tie in points of the high voltage transmission system.

Topography

The importance of topography is tied in with the routine releases of gaseous wastes from the operating plant and it is necessary to know what the micro meteorology at the site might be. The normal stack release from reactors is of greater concern for valley locations when the top of the stack is below the level of the surrounding hills than it is for the flat sites.

Geology

Geologic structures such as faults, fractures, joints and folds in the vicinity of the site must be thoroughly studied and their tectonic significance to the stability of the site evaluated. Faulting is an especially critical feature of a site as the probability of surface displacement at or very near the site would eliminate a site from practical consideration. The stability of existing slopes and landslide potential have to be taken into consideration. Construction on cut slopes must include allowance for seismic activities.

Groundwater conditions at the site must be known. The depth to water, and the direction and rate of groundwater flow must be determined for purposes of foundation design and estimating construction problems related to groundwater control. A knowledge of these conditions is also necessary to evaluate emergency actions if radioactive material is accidentally discharged at the ground surface.

Flooding

Flooding due to an overflow of nearby rivers has to be considered along with the effects of typhoons and tsunamis. It is usual to derive the possible maximum flood, for example, as defined by the US Army Corps of Engineers and use this as a possible flood which the structure must be designed to withstand. The nuclear portions of the plant must be protected against the effect of such floods, i.e. the structure housing the reactor and other critical services such as the radioactive waste plant, the emergency diesels, generator building, etc. No flooding of the structure housing the critical nuclear equipment should be allowed.

Meteorology

Meteorology is an important factor in the location of both nuclear and thermal plants due to the disposal to the atmosphere of gaseous effluents from normal plant operation. In the case of nuclear plant operation this is also a consideration in view of the possible release of radioactivity. However, micro meteorology for a given site is often of much greater importance, even if the data are limited, than the wealth of data which can be obtained from a meteorological station which is, however, some distance away from the site.

Tsunamis

Tsunamis must be considered in the design of a nuclear plant located near coastal areas in earthquake zones. To obtain a valid estimate of a maximum wave height for site evaluation the following topics should be considered:

- Location and magnitude of the design earthquake with an epicentre at sea
- The effect of shoreline configuration on reflection or amplification of tsunamis.

The effect of any barriers or obstructions between the estimated epicentre and the site must be considered. The effect of tsunamis originating in the general area of the site, as well as those whose origin is quite distant should be evaluated for the design maximum wave height at the site.

Seismology

Of all the physical characteristics of the site which must be considered, seismology is potentially the most troublesome. The IAEA has published Earthquake Guidelines for Reactor Siting (Technical Reports Series No.139, IAEA, Vienna (1972)). In it is summarized what information and investigations, geologic data and engineering data are recommended for a site in an earthquake zone. This is a very important investigation and can have a considerable impact on the cost of the nuclear plant when constructed in an earthquake zone. It is necessary to establish what horizontal and vertical acceleration the plant must withstand; also what the earthquake spectrum and damping factor for the foundation must be, with potentially very important cost implications.

2.5. Public information

While authorities around the world are now in general agreement about the necessity for nuclear power, in some countries serious public discussions have come up in recent years about the acceptability of the risks which nuclear power entails and, indeed, whether nuclear power should really be regarded as a viable alternative.

Historically, this nuclear controversy arose in the United States around 1968. Its origin did not lie in the lack of correct information or in the lack of ability of responsible authorities and utilities to produce such information when required. Rather it seems to have been a question of the ability to communicate, in the sense that it is "impossible to be too simple" and scientists wishing to be accurate find it difficult, if not impossible and unethical, to oversimplify.

At the root of the problem was also the fact that in the United States it was the same body which was both promoting the use of nuclear power and establishing regulations and licensing procedures. This duality of functions has been one focal point for criticism.

In the early years, some particular cases were brought to the attention of the public and then became issues for the controversy. The safety of nuclear reactors was questioned and this transformed itself in technical issues such as the questions on emergency core cooling systems and the effects of releases of waste heat. Undoubtedly, misrepresentation of originally correct information has played an important role in the growth of the public debate, but it generally seems to reflect genuine fears on the part of the public, fears which are partly due to lack of understanding of nuclear power and its risks and also the inability to compare these risks with others which are accepted in daily life.

Another factor to be taken into consideration in the development of the controversy is the attention given to sensationalism. Forecasts of disaster invariably attract immediate attention, while correct, safe and uneventful operation of anything over a long period of time rarely gets a mention. And today, nuclear industry has an experience of over 1000 reactor years without accident. As the Swiss Federation Commission of Radiation Protection has indicated "in the field of nuclear energy, we are in the unique position that the safety provisions preceded technical realization and do not as in the field of water and air pollution lag behind".

In short, the ultimate and general acceptance of nuclear power must depend on and will result inevitably from adequate public education. A key element in dispelling the public's concern in nuclear safety is finding ways to define easily technical issues in a language that the average man and woman can understand. Experience and familiarity are also wonderful teachers. This is probably the reason why many of the most outstanding examples of complete public acceptance of nuclear power found in the United States of America were among the population living close to operating nuclear plants.

For these reasons it is necessary to establish early in a nuclear power programme an active public information function aimed both at the population around the future reactor sites and the general public. It goes without saying that the distributed information must be unbiased, correct and complete, and the work performed very competently. This work will undoubtedly grow to be a full-time qualified professional effort which must be based on good knowledge not only about nuclear power but also about local conditions. Many problems of misinformation and negative public reactions can be avoided if this function is handled properly from the very beginning.

The IAEA can assist national atomic energy authorities in this matter. It is able to provide a wide range of balanced and accurate information material, including pamphlets and information kits intended for the general public, and substantial and detailed studies on nuclear power and the environment, waste management, safeguards, etc., designed for the plant operator and other technically more sophisticated audiences. It can also provide films, arrange for answers to specific questions and generally advise on the development of adequate public information mechanisms.

2.6. Waste management and environmental considerations

(a) Sources of radioactivity

Both nuclear and conventional power plants use much the same type of machinery to convert steam to electricity, and to connect this to the electrical grid. The uniqueness of the nuclear plant lies in the fuel used, and more particularly in the equipment needed to maintain strict control over the radioactive materials formed by the fission process that generates heat.

Fission products

The principal radioactive materials formed are the fission products. The quantity of fission products formed is small in terms of mass: in a large power plant this will amount to only a few kilograms each day. Since some of the fission products decay as others are formed, the amount of radioactivity levels off and the inventory of short-lived fission products reaches essentially a steady value. Because the shorter lived radionuclides contribute substantially to the total inventory of radioactivity in terms of curies after a few weeks of operation of a light water moderated power reactor using fuel slightly enriched in U_{235}, the fission product inventory might be up to about 40% of what would exist after a two-year operating period. More importantly, all but a very small fraction of the radioactive fission products remain confined within the fuel element where they were formed and will not be released from the nuclear power station in normal operation. The quantity of fission products within reactor fuel elements will depend upon:

(i) Average operating power level of the reactor;
(ii) The time that the fuel has been in the reactor core; and
(iii) Time elapsed for radioactive decay.

Activation products

Structural materials used in the reactor and the primary heat removal system will corrode and erode only very slightly with time — but enough to create fine particulates identified broadly as "corrosion products". These corrosion products, along with other impurities in the coolant, circulate through the core of the reactor, where they are exposed to neutrons. Neutron bombardment causes them to become radioactive. The quantities of radioactive materials so formed are small compared with the fission products, and consist commonly of radioisotopes of elements such as iron, cobalt and manganese. Some reactors use boron in the reactor core and core coolant to control the fission process. Neutron absorption by boron leads to the formation of tritium, a radioactive isotope of hydrogen. Tritium formation similarly can result where water is used as the core coolant, through conversion of deuterium — a natural isotope of hydrogen found in water. In gas cooled reactors, cooled with carbon dioxide, the activation products include radioactive isotopes of carbon and argon.

(b) Radioactive waste generation and management[2.2]

Although the kinds of radioactive wastes produced as by-products of the fission process are basically the same for all uranium-fuelled reactors, the characteristics of the effluents from plants can vary appreciably, depending on the reactor coolant and steam cycles used. The radioisotopes in the effluent streams in turn influence strongly the design of particular waste treatment systems.

The objectives in plant design and operation are to process and recycle waste steams in such a way as to minimize both volume and radioactivity of the effluent wherever feasible. Releases to the environment are controlled by processing of effluents, by decay storage and by monitoring before discharge to ensure that releases do not exceed permissible limits, which must be established by the regulatory authority.

In addition, solid wastes will accumulate at a steady rate and adequate arrangements must be made for their storage and/or disposal.

All this implies that a waste management policy must be developed and must be approved by a regulatory authority. Ideally this should be done before bids are requested, thus standardizing the conditions of bidding for the waste treatment plant. As the latter may cost 3 - 5 per cent of the total, depending on the requirements and the equipment provided to meet the requirements, it can be seen that this is a worth-while aim.

(c) Thermal discharges[2.3]

All steam-powered electrical generating plants, whether fired by fossil or by nuclear fuel, have a common potential problem in their need to release unused heat to the environment. Heat from the combustion of fossil fuel or from the fission of nuclear fuel in a reactor is used to produce steam at high temperature and pressure, which drives a turbine connected to a generator. The "spent" steam from the turbine is condensed by passing through condensers cooled by large amounts of water. The heat transferred to the cooling water normally raises its temperature by a maximum of 5° - 15°C under full load conditions.

The reactors on the market at present operate at a lower thermal efficiency than most modern fossil-fuelled plants of the same generating capacity. For this reason, and also because about 10% of the heat from fossil-fuelled plants is discharged directly into the atmosphere through the stack, nuclear plants reject about 50% more heat to the cooling water than fossil-fuelled plants. This difference should be reduced in the future with the advanced reactors now being developed.

Nuclear plants on average use about 50 litres of cooling water per second per megawatt, with an average maximum temperature rise across the condenser of about 10°C. Fossil-fuelled plants require about 37 litres per second per megawatt for a maximum temperature rise of about 9°C.

[2.2] For further information see IAEA Information Booklet: Nuclear Power and the Environment, IAEA, Vienna (1973) 22-39.

[2.3] For further information see IAEA Information Booklet Nuclear Power and the Environment, IAEA, Vienna (1973) 56-60, and Thermal Discharges at Nuclear Power Stations, Technical Reports Series No.155, IAEA, Vienna (1974).

Various constraints including economic and biological costs, aesthetics, statutes on water quality and cooling water sources govern the choice of the method of disposal of condenser cooling water. One of the most important factors is the source of cooling water available for a particular steam/ electric plant. The body of water to be used may range from fresh water lakes and rivers to estuaries and coastal marine waters. In many countries or in parts of them there may be little choice but to use estuaries and coastal waters because there are insufficient lakes or rivers.

Basically, there are three methods of disposal of heated discharges:

- By a closed-cycle cooling system;
- By a variable-cycle cooling water system; and
- By once-through operation.

In a closed-cycle system the condenser cooling water will flow from a condenser to an atmospheric heat exchanger (either a cooling tower or an artificial lake or pond) where it will lose heat before being returned to the condenser for re-use.

A variable-cycling cooling water system rejects some of the heat from the condenser cooling water in a cooling tower or flow-through cooling pond before discharge into a natural water body. Some of these systems are capable of operating at any point between the two extremes of closed-cycle and once-through operation.

When the supply of water is not a problem, plants may use the once-through system, in which the cooling water is taken from nearby rivers, lakes, estuaries or coastal waters and returned usually to the same source.

Engineers and biologists are making considerable efforts to take into account the needs of both the aquatic biological community and the power plant in developing suitable designs for power plant cooling systems. Physical studies concerning water temperatures enable some predictions of temperature patterns resulting from heated discharges to be made. Information on temperature and behaviour of heated discharges from the site is needed:

- To avoid recirculation of heated discharge waters, and thus to increase plant efficiency;
- To comply with regulations on water temperature standards; and
- To provide sufficient basic data to enable biologists and ecologists to assess thermal effects.

Perhaps no other single environmental factor affects aquatic life as profoundly or in such an all-pervasive manner as temperature. Unfavourable temperature may affect reproduction, growth, survival of larval forms, juveniles and adults, and all the life processes necessary to maintain a healthy state. A host of biological and ecological questions may be asked about possible damage to aquatic life in waters receiving heated discharges, and no reasonable person recommends uncontrolled release of heated water. Regulatory agencies at various levels of government are developing or have established water temperature standards which are used to govern heated discharges from steam/electric plants. If discharges of heated water are controlled then the primary concern is in "monitoring" effects to make sure that no serious trends requiring corrective action are taking place on account of subtle temperature effects on populations, communities and ecosystems.

(d) Chemical aspects

Normal operation of a nuclear power plant requires the discharge of certain chemicals from the turbine condenser cooling system, the radioactive waste system, the regeneration of process water demineralizers, the laundry waste system and the sanitary waste system. The chemical content of the discharge from these systems will vary from plant to plant. For example, chlorine or some other biocide may be added intermittently to cooling water to remove accumulations of organic matter inside the condensers; phosphate and zinc compounds may be used as corrosion inhibitors; sulphuric acid may be used to adjust the alkalinity of recirculating cooling water; and demineralizers may be regenerated periodically with sulphuric acid and sodium hydroxide, the regenerants then being neutralized before discharge. The maximum concentrations of some of these chemicals in the discharge canal could conceivably exceed levels which are toxic to aquatic life. Temperature as the "master factor" affecting rates of all metabolic functions, can influence the speed with which toxic substances exert their effects and, in some instances, it can influence the threshold concentrations for toxicity.

The technical assessment of the potential impacts of chemical and sanitary wastes from nuclear plants is included in the environmental evaluation made in the early stages of planning. The sources of potential biological damage considered include: moisture from cooling tower plumes and airborne spray drift; chemicals from tower blowdown; chemicals from airborne spray drift on surrounding land and vegetation; and chemicals such as chlorine that may be toxic to aquatic life. Assessments such as these guide those who must supply solutions to meet water quality standards.

(e) Accidental events

Experience acquired in many countries in the safe operation of different types of power reactors has been impressive and encouraging and the abnormal events that have occurred have not jeopardized public safety. Nevertheless, the sum total of the experience that has been acquired is still quite limited, and it cannot be said that the probability of an accident serious enough to have consequences off-site is zero.

Many assessments of the potential consequences of postulated accidents including the release of radioactive materials beyond the site boundary have been made, the last being the so-called Rasmussen study.[2.4] The general trend of these studies, which have been progressively developed and refined, has been to show a decrease in the consequences of accidents, so that the risks to an individual in a country with a major nuclear power programme are now judged to be much lower than those from natural events such as earthquakes, floods and lightning, and very much lower than the risks posed by e.g. modern traffic conditions.

[2.4] Reactor Safety Study, An Assessment of Accident Risks in US Commercial Nuclear Power Plants, WASH-1400, 1974.

Governmental authorities require generally that emergency plans be prepared in advance to cope with situations such as a reactor accident. The main measures to be taken include:

- (i) Rapid survey to delineate the direction and extent of the plume of released radioactivity;
- (ii) Warnings to and instruction of the population;
- (iii) Restrictions on the movement of people, the consumption of milk, water and food from contaminated areas, and so on;
- (iv) Prevention (if possible) of the extension of the accident;
- (v) Survey of and medical assistance to irradiated persons.

2.7. Relationship between the regulatory authority and the project group

Strict definitions of the rôles of the regulatory authority and the plant owner are given as recommendations in IAEA's published Guidelines for Organization and Conduct of Regulatory Activities for Nuclear Power Reactors (Technical Reports Series No.153, IAEA, Vienna (1974)). In practice, it will, however, be difficult to follow such strict definitions, particularly for a first nuclear power project during which the whole permit and licensing process will presumably be developed in detail and when the detailed requirements for permits at the siting, construction and operation stages have not yet been established.

In this situation, it will be necessary to have a relationship between the project group and the regulatory authority which is based on mutual confidence and close co-operation without violating the basic principle of independence between the regulatory body and the owner/operator of the plant. It will be necessary to foresee at each stage the probable final requirements which will be posed for permits. The Agency has in publications and in its codes of practice, e.g. Guidelines for the Layout and Contents of Safety Reports for Stationary Nuclear Power Plants (Safety Series No.34, IAEA, Vienna (1970)) and Safe Operation of Nuclear Power Plants (Safety Series No.31, IAEA, Vienna (1969)), laid down basic criteria and it will in the future continue to publish codes of practice, guides and manuals, which will help to provide a basis for the regulatory review process in any country. It will still be necessary to obtain more detailed guidance on practical aspects from IAEA and from other sources. One practical way can be to use the regulatory requirements in the country from which the reactor is bought and there are ways to facilitate this, e.g. by using a "reference plant" concept which will be discussed later in Section 5.

In order to avoid problems at a later stage, resulting in additional requirements, back-fitting, etc., it will under all circumstances be necessary to establish a very close working relationship between the project group and the regulatory body from the very beginning of siting studies.

3. THE FEASIBILITY STUDY

A feasibility or pre-investment study for a nuclear power plant project in a country is the second in a series of steps towards a nuclear power programme, each one representing ever increasing involvement, commitment and expenditure. The initial step mentioned previously was a nuclear power planning study, performed possibly with the help of the IAEA. To this study the organizations formed for the purpose in the country can now add various national considerations: organizational, political, financial, etc., in the next step, the feasibility study.

The feasibility study must be much more specific than the nuclear power planning study. There is no doubt that a well-performed nuclear power planning study will make a considerable contribution to a feasibility study. It will have helped to define several of the economic and technical parameters which will be the basis for the feasibility study, such as maximum unit sizes which can be introduced in the grid, timing, approximate location and the economic ground-rules. A feasibility study must, however, first of all address itself to a specific plant at one or possibly two alternative sites. Since it requires a greater expenditure and will probably result in a firmer commitment, it is also necessary to review the organization for nuclear power within the country. In particular, it is necessary that all authorities in the country which may be concerned with a later project have the possibility to express their points of view, for instance in a co-ordination committee (Section 1.5). This co-ordination function is of great importance to avoid set-backs in the project at a later stage, because important national interests were not considered from the beginning.

A feasibility study is likely to cost between $100 000 and $300 000 depending upon the scope of the study and this high cost again stresses the necessity to prepare carefully for the work both by setting up an organization with an appropriate staff and collecting the input data and information on any limiting conditions resulting, for instance, from national policy from all sources.

At the time of preparation for the feasibility study it is also highly desirable that legislation is enacted and at least the nucleus of a regulatory body set up to review the proposed sites, possibly with the advice of the IAEA.

This is also the time when national policies should begin to be formulated concerning domestic industrial participation in a first project, maximum exploration and development of fuel fabrication capability.

It is essential that one organization should be fully in charge of ordering and executing the feasibility study, most naturally the future project group, e.g. in the electric utility.

3.1. Objective and scope of the feasibility study

A feasibility study is the initial trial fitting of a specific nuclear power station at a specific site, into a national electricity grid and, in doing so, should answer a series of important questions:

(i) What size of nuclear station can be used most economically?
(ii) What are the detailed economic prospects of the station compared to alternatives?
(iii) Are there specific problems associated with the site?
(iv) What type of organization must be set up to build and operate the nuclear power station?
(v) Which staff and what type of training programme are required within the country to achieve an operating nuclear power station?
(vi) How can a nuclear power station be purchased and financed?

The report completed at the end of a feasibility study should answer all of these questions.

A sample table of contents of a feasibility study report is given in Table 3.1. Each one of the sections will require a sizeable effort and it should in particular be noted that the outline designs and capital cost estimates will have to be performed in a fair amount of detail taking local conditions fully into account.

Although there may be considerable motivation to have the feasibility study performed by a national organization, e.g. the electric utility which may have performed similar studies for conventional thermal power stations in the past, it is normally recommended to hire a well-known firm of consultants for the study of the first nuclear power project. The reason is not only that the technology will be new to local authorities but also that the feasibility study will be of importance in the negotiation of financing for the project and it can be expected to carry more weight in this context if performed by an established and neutral firm.

The IAEA has executed feasibility studies in the Philippines by using consulting firms. These feasibility studies have been done with financing under the United Nations Development Programme, but Agency assistance could also be available for guidance and help in nationally financed feasibility studies.

If Agency help is contemplated, it should be sought as early as possible and could involve the following specific tasks:

(i) Reviewing the sites and advising on site safety and engineering aspects, with recommendations as to further data required.
(ii) Assistance with preparing tendering documents for bids for hiring a consultant and evaluating the bids, and with defining the terms of reference for the study.
(iii) Critically reviewing and commenting on the consultant's report on the feasibility study.

It is essential to define with great care the scope of the study and the terms of reference under which it is to be performed (e.g. with relation to site, unit sizes, economic parameters, and national policy) before the study is to be started by the consulting firm. Some of the aspects which should be covered by the study are briefly discussed in the following.

(a) Site

A feasibility study should be performed with specific sites for the power station in mind, to enable the study team to concentrate on the characteristics of one or two of the most suitable of these sites without wasting time. Construction and transportation costs will, of course, vary from site to site. Finally, the study should initiate the collection of the detailed specific data on the environment of a site which are vitally necessary before a final choice for a power station site can be made. Such data can only be collected over a period of several years. The type of information that must be obtained has been briefly outlined in Section 2.4. It will now only be repeated that it is necessary to establish data collection for the site itself, as the specific, local conditions can be of very great importance not only for the choice of the site from a safety point of view but also for the construction.

TABLE 3.1. TABLE OF CONTENTS OF FEASIBILITY STUDY REPORT

1. INTRODUCTION
    - 1.1. Background information
    - 1.2. Objectives
    - 1.3. Scope and implementation
    - 1.4. Recent developments
2. LOAD PROJECTION
    - 2.1. General system characteristics
    - 2.2. Future electricity demand
3. CHOICE OF UNIT SIZE
    - 3.1. Size selection
    - 3.2. Station size
    - 3.3. System analysis
    - 3.4. Site considerations
    - 3.5. Staffing
4. SYSTEM EXPANSION
    - 4.1. Expansion programmes
5. OUTLINE DESIGN OF NUCLEAR PLANT AND ALTERNATIVE PLANT AND CAPITAL COSTS
    - 5.1. Design characteristics
    - 5.2. Construction schedule
    - 5.3. Basis of cost estimates
6. OPERATING COSTS
    - 6.1. Oil fuel
    - 6.2. Nuclear fuel
    - 6.3. Operation and maintenance
7. GENERATION COSTS
    - 7.1. Annual charges
    - 7.2. Total generating costs
8. STAFFING AND TRAINING REQUIREMENTS
9. SITE CONSIDERATIONS
10. ORGANIZATIONAL AND FINANCIAL REVIEW
    - 10.1. Project organization
    - 10.2. Financial review of existing utilities
    - 10.3. Financial requirements of nuclear programme
    - 10.4. Financial projections for participating utilities
11. INVESTMENT CONSIDERATIONS
    - 11.1. Contact with financing institutions
    - 11.2. Evaluation of alternative programmes
12. CONCLUSIONS AND RECOMMENDATIONS
    - 12.1. Feasibility of nuclear power
    - 12.2. Further steps to be taken for implementation

(b) Load forecast review

The next step in the feasibility study is a review of the growth of the electricity requirements. This review will need, in addition to the work done by the planning authorities, some basic economic data in order to verify or modify the load forecasts.

Where data on system expansion are not available or have been collected only on a very rough basis, a micro-economic review of the market should be carried out. A more accurate forecast of system expansion over a period of 15 to 20 years can then be derived. Since this is required for any generating plant expansion, its importance is obvious.

Special attention must in this context be paid to the growth of industrial loads as they may influence future demands to a major extent. In this case it is particularly essential to include in the reviews information from other authorities such as Development Boards, Planning Commissions, Ministries of Economy, etc., in order to get as complete a picture as possible of all development plans.

The characteristics of the electricity demand and its daily, weekly and seasonal variations must also be forecast and reviewed in detail in order to form a judgement on the types of generating plant which will be needed and how they can best be fitted to meet the demand.

Detailed load forecasting is generally performed by the electric utilities or generating authorities either within their own organizations on a continuing basis or periodically by outside consultants. Forecasting is a complex and sophisticated activity which naturally is at the very basis for any future planning. The feasibility study for a first nuclear plant must contain a critical review of the current load forecasts, but it cannot be expected to provide a new, independent forecast, as this would be a major task outside the real scope of the study.

(c) Review of the generating and transmission systems

The next step in the feasibility study is a review of the existing and projected generating capacity and transmission system lines. Detailed information is therefore required on the existing and planned generating capacity, showing the types of generating capacity in use, i.e. hydroelectric or fossil fuel, and indicating the system reserves and the reliability criteria employed, to meet the peak load conditions. Statistics on system failures, brown-outs, etc. are needed. The operating plans for various generating stations and the load factors achieved and planned are also important, and the transient stability of the future transmission system must also be analysed in this review.

The consultant will on this basis determine the biggest unit size which can be accepted into the system at a particular point in time, which is of fundamental importance to achieve the best generating economy. He may further be able to make recommendations on economic improvements of transmission facilities to permit either larger stations or better distribution of the energy generated by existing stations.

(d) Economic analysis

With the background information on the system, the consultant can begin to plan specific expansion programmes incorporating nuclear power alternatives for needed generating units. Since the system is interconnected and since the load growth must be met by a number of generating facilities with interrelated requirements, this part of the system study is most often accomplished by studying a number of cases consisting of proposed expansion programmes including all facilities for the planning period. These cases may use various mixtures of conventional and nuclear power stations. Part of this work will have been performed in a carefully made nuclear power planning study which should have given an indication of an optimum expansion plan. On this basis, it will be possible to concentrate the work on a specific project for which alternatives are studied in greater detail, in particular to obtain more realistic cost estimates based on detailed outline designs and carefully taking into account availability and costs of local labour, local construction practice, site conditions, etc.

Finally, by means of present-worth analysis, using a realistic interest rate and assumptions about costs, the feasibility study must demonstrate that the recommended new unit will be economically competitive. In this demonstration, the terms of reference specified to the consultant at the beginning of the study may largely dictate the results, and they must be realistic and fairly chosen.

The results of the study should further indicate to what extent the terms of reference are being met. For example, if one of the terms of reference were a policy to diversify the sources of energy used, then the recommendation of a nuclear power station would achieve a diversification, but a 500 MW station in a 10 000 MW grid would represent a low percentage of diversification.

The study is an excellent opportunity to train a number of scientists, engineers, mathematicians and other professional persons in the country. It includes a load forecast review and the consultant will require help from many local authorities. Staff can be trained in statistical analysis methods for load forecasting, site evaluation, and in methods of comparative evaluation of conventional and nuclear power plants, both from the technical and economic standpoints. The study should also be used to the fullest extent for training intermediate level professional people, particularly within the future nuclear power project group.

In one way the recent drastic increases in the oil prices could tend to simplify the economic aspects of the feasibility study, as nuclear power would be competitive with oil at world market prices for all base-loaded stations above at least 200 MW(e) output. A careful economic evaluation should still be performed to avoid surprises later in the project work. Even where the competitivity with oil is evident a proper system expansion study should be performed in which a nuclear power station should compete with other alternatives, in particular perhaps less easily accessible hydro projects which may have been discarded or considered uneconomical earlier.

(e) Organizational structure

The history of electric power generation and its production organization in the country should be reviewed under the feasibility study. In many countries early development was initiated by private firms engaged in, e.g. mining, in order to meet their own needs, and they supplied other consumers with electric power as a side line. At some point in time, the government authorities recognized the importance of electric power supply and became involved in the generation and distribution of electricity. This development has varied from country to country and the government's involvement may now range from some control of private utilities to the establishment of a single national generating authority. The transmission grids within the country are often a reflection of historical development and may not be the grids which would be constructed today if the country had the choice of replacing them.

The review of this development serves to establish the background and the present structure of the network of generating sources and electricity distributors. A nuclear power plant usually represents the largest investment for a single generating station within a country. To execute this investment, an organization is necessary with developed capability and strong competence not only for the purchasing procedure of a nuclear power plant as described in subsequent sections, but also for participation in the project, for overseeing the contractor, performing the quality assurance programme, etc. Finally, it must have sufficient financial backing to undertake an investment of that order of magnitude. Since, in many countries, the power generation may be the task of several organizations, the feasibility study must also recommend workable organizational arrangements for the project work and the operation of the nuclear power station. In this field, the recommendations of a competent outside authority are usually more acceptable.

(f) Financing

The results of a feasibility study have little value if they do not include recommendations with respect to financing. It would, for example, not be very useful to recommend a 600-MW(e) power plant, prove that the size is economical and that an organization can be formed which is capable of executing the project if no recommendations can be made regarding the financial aspects. In the past, suppliers have been prepared to assist with financing of nuclear power projects on extremely favourable terms. This type of financing may still be available for the first station within a country but it can no longer be expected that such favourable financing will be assured. The consultant should therefore seek the advice of commercial financial institutions and of development or aid institutions and base his opinion on this advice as to the financial potential of the project.

3.2. Review of the feasibility study

The feasibility study is basically a systematic review of an electrical system in which a nuclear power station is to be installed. The report should indicate whether nuclear power is feasible – technically, economically, organizationally and financially. It should further indicate the sensitivity of the results to changes in some of the basic parameters used, e.g. future costs of alternative fuels.

The feasibility study is furthermore done with a limited budget and is required to produce results within a limited time. The resulting report may therefore contain a number of conditional statements. Each of these represents a point of insufficient information, in either availability or in accuracy. The report should contain a statement which summarizes the sensitivity of the results to these assumptions.

Because of the assumptions which have to be made, and the conditional character of the results it is essential that a careful review is made of the feasibility study, for instance within the framework of the co-ordinating committee (Section 1.5), to assure that the assumptions are acceptable to all authorities and organizations concerned. In the course of such a review it is possible that alternative solutions, e.g. earlier or later introduction of the nuclear power project, would be given preference to the recommendation in the feasibility study. It should be the project group's responsibility to detail the economic and other consequences of such a decision.

4. PRE-PURCHASING ACTIVITIES

Once the feasibility study has demonstrated that a nuclear power programme is economically desirable within the country and that it is possible to set up an organization which is technically capable of utilizing nuclear power stations, a decision in principle has to be taken most often at government level to purchase the first nuclear power station. Purchasing a nuclear power station is, however, fairly complex and a number of tasks must be carried out before bids are requested. These are discussed in this chapter under the general heading "pre-purchasing activities".

4.1. Organization and manpower requirements

In Section 2.3 the basic organizational and manpower requirements were briefly introduced and it was assumed that for the feasibility study at least the cores of both a regulatory organization and a project group existed. When the decision in principle has been taken to go ahead with a nuclear power project it will be necessary to recruit additional staff for both these organizations. It will in most cases be very difficult to find persons with appropriate qualifications and it will thus be necessary to send many abroad for training for a period of at least 1-2 years immediately upon recruitment. It is thus an absolute necessity to establish staffing policies for both organizations, which allow not only for an adequate number of staff at the appropriate levels and salaries, but also for enough lead time in their recruitment to permit training abroad.

The regulatory authority will at this time have to take a definite stand on the proposed site for the nuclear power plant if all the necessary information is available to it. It will also prepare itself for the review of the safety analysis report. The legislation providing for these actions must thus exist. It is suggested that these activities will require a staff of about six highly qualified professionals at this stage, depending to some extent on the approach chosen for review and issuance of the necessary permits and the degree of reliance on advice from outside sources, such as the IAEA.

The project organization (Fig.2.6) must now be equipped to take the initiative for inviting bids for consulting services and from plant suppliers for starting activities related to the site, safety report, selection of reactor type and fuel cycle, to review domestic participation capabilities and critically review proposals made by suppliers. This will require a formally established project organization growing rapidly from some ten to around 20 experienced professionals. There are also obvious advantages with having at least the future operations superintendent participate in the early project work.

It will be possible to get the future plant operations group trained by the main power plant vendor and this is most often a routine requirement in the main contract, but it is much more difficult to obtain training facilities for the project group which has to be formed before the choice of a supplier and for which on-the-job training is essential. The IAEA is trying to set up training courses and identify organizations where experience can be gained. It is important to recognize that for most of the posts in the project group it is more desirable to find engineers with good experience from other major projects such as hydro power stations, conventional thermal power stations or refineries, rather than nuclear specialists with a scientific background. These would to some extent already be available in the utility or generating authority within which the project group would normally be set up. The manpower requirements of 10-20 professionals assumes that considerable help from the outside is available from a consulting firm with experience from nuclear power projects.

4.2. Selection of a consultant

The consultant will be needed for a broad range of activities and would naturally be able to give the best service to the project if he is retained at this point in time and kept on for the duration of the project. The agreement under which he is retained must, of course, indicate that his services can be terminated if, at the end of the pre-purchasing activities, a decision to proceed with purchasing cannot be made or it is decided to purchase a reactor type of which he has no experience. If engaged at this point, he can expect to assist the project group from the pre-purchasing activities through bid document preparation to construction, when he may act as an advisor and responsible engineer.

The utility or generating authority will already have worked with consultants on other projects and in various studies and will know how to select and hire them. A procedure commonly used is to ask consultants to bid on a specific basis for the work. If this procedure is followed, the bidding process should be used only to ensure competition, and firms that are asked to bid should be pre-selected. In pre-selecting the firms, a number of aspects should be considered, such as:

(i) Is the consultant knowledgeable on nuclear power plant projects and is the type of reactor with which he has experience, one which could be chosen for the country;

(ii) Has he worked in the country on other projects, and is he knowledgeable on the country or the area;

(iii) Does he have any ties with a specific manufacturer;

(iv) Does he have continuity in his staff from other nuclear power projects;

(v) Is the consultant limited to the engineering aspects of the work or is he also capable of covering economic and financial aspects.

The rôle of the consultant throughout the preparations for the project and the construction is likely to be much more important in the case of a nuclear power project than for a conventional thermal station. His first tasks may have been the conduct of the nuclear power planning and the feasibility studies. Other tasks during the pre-purchasing activities are likely to include:

- Assistance with budgeting, forecasting cash requirements and financing plans and contacts with financing institutions, such as IBRD, etc.;
- Surveys of local industry to assess the capabilities for manufacture of some components and of what training and new standards would be required;
- Advice to the plant owner on safety reviews, regulatory requirements and nuclear liability protection depending on how well developed national nuclear legislation and regulations are;
- Site evaluations and environmental studies to determine the suitability of the given sites; and
- Advice on reactor type selection.

During the later stage he would be called upon to develop technical specifications and criteria for the plant to be purchased, advise on contract type, prepare bidding documents and evaluate bids. Finally, he may, depending upon the contract type, have a major rôle as adviser during construction. During the entire project work he should provide training of the project group staff by reviewing their work and by using them under supervision in test and inspection work. It is obvious that there would be a great advantage to retain the same consultant during the whole of this period but it is at the same time necessary to ensure that the best possible advice is obtained at each stage and a contract form with the consulting firm permitting options for rehiring at each stage is thus suggested.

4.3. Site data requirements

In Section 2.4 a short description was given of the data requirements for preliminary selection and evaluation of a site, mainly from a safety point of view. For the final report on the site to the regulatory authority and for preparing the bidding documents for the plant, the information requirements are, however, much more extensive and specific and it is now necessary to devote a systematic effort to data collection at the site over a period of 1-2 years.

A check list on the data requirements has been compiled in Annex 4 reflecting, in particular, the site information which should be included in the documents calling for bids on the power station. The list is quite extensive, and in general it would also include most of the information which would be needed for the safety report and review before issue of a definite permit to use the site for a nuclear power plant. It is essential that the information really is representative of the local conditions at the site and it will be necessary, for instance, to get the meteorological data from a small meteorological station installed on the site itself, and not from airports or harbours at a distance from it.

Furthermore, it will be necessary at this stage to start the environmental monitoring which will have to be continued throughout the plant's lifetime. Several IAEA publications cover the requirements for environmental monitoring, principally: Objectives and Design of Environmental Monitoring Programmes for Radioactive Contaminants (Safety Series No.41, IAEA, Vienna (1975)), Manual on Environmental Monitoring in Normal Operation (Safety Series No.16, IAEA, Vienna (1966)) and Environmental Monitoring in Emergency Situations (Safety Series No.18, IAEA, Vienna (1966)).

It must again be emphasized that the site data collection is the continuing responsibility of the future owner of the plant, who must perform the planning and definition of the scope for the work. Only part of its initial execution can be contracted to other organizations or consulting firms.

4.4. Reactor type selection

At the present time there are a number of different types of power reactor in operation in the world, but the choice of a reactor to a country embarking upon its first nuclear power project may be more limited than this number would indicate. The reasons for this will be given in more detail in the following.

Generally speaking it is advantageous to wait as long as possible with the choice of reactor type in order not to lock positions in relation to any specific suppliers until this is necessary. A comparison of bids for very different power reactor and plant types will, however, be extremely complicated and difficult. It is thus a definite advantage to limit the final bidding to suppliers of one well specified reactor type, at least as long as this will still give possibility for competitive bidding by several suppliers.

The basic considerations which have to be taken into account in the choice of reactor types include the following.

(a) Provenness

Complex equipment which incorporates new technology, new design or new materials, or is produced by particular firms for the first time can only be acquired with risk: The risk of production units not working to the standards of prototypes, or inexperienced producers not being able to manufacture to specifications and/or to schedule. These risks can be substantial for electric power utilities acquiring a large generating plant, ranging from the economic burden of capital and operating costs exceeding expectations to the risk of not having the plant available when needed. The only protection against such risks is to confine procurement to proven equipment and manufacturers. Judgements of "provenness" can only be based on actual operating experience with the equipment.

Financing institutions have applied criteria of provenness in the past in order to minimize the risk to themselves. The World Bank, IBRD, has, for instance, applied a criterion to all equipment it finances, and specifically to nuclear, defined as follows:

"... when a complex mechanical plant is required (and this covers a broad range from thermal power plant to locomotives) a developing country should limit its consideration to makes and designs which have already been manufactured and operated successfully in some other country's system. This view is based on two principal foundations, namely:

(a) A developing country requires even greater reliability of operation than a developed country and demands an even greater assurance of the successful outcome of any project investment; and

(b) The Bank has been familiar with numerous instances where complex equipment, even though manufactured by well-established and generally reliable firms, gave serious and long-lasting difficulties in the case of prototypes even when no new principles were involved.

As all of these considerations are valid a fortiori in the case of nuclear plants, which involve radical new principles and technologies, the Bank would consider it risky for a developing country to install plant having basic design and components which differ materially from what has been in successful utility operation elsewhere. Only installations which meet the criteria outlined above will be referred to as "proven". In this context, a substantial size extrapolation is sufficient reason for the criterion not to be met."

In practice this criterion of "provenness" applied to nuclear facilities has been taken to mean reactor and turbo-generator systems in satisfactory commercial operation for not less than one year.

It will in practice also mean a limitation to those manufacturers who have earlier supplied these systems.

(b) Long-term commitment

As discussed in Section 2.1 (c) and (d) the choice of reactor type for the first nuclear power plant should also be seen as a possible long-term commitment to that type for several more units to be built under the foreseeable nuclear power programme and also to the type of fuel cycle and associated international supply requirements. Although it would be desirable that the decision on the first nuclear power plant should be taken on as purely economical grounds as possible, the choice of the reactor type for that plant will have to take into account economic uncertainties with each available system for a long-term future. Because of the international supply, and potential international long-term commitment for both the reactor plants and the fuel services, political considerations may also have to enter into the decision. Furthermore, it is necessary to bear in mind the development potential of the reactor systems and the possibility of early obsolescence when the choice is to be made. While early obsolescence would not appear to be a real risk for any of the presently commercially available power reactor systems, this could well be the case for a less proven system particularly if its economic advantages are marginal or, for example, largely influenced by interest rates.

(c) Use of local fuel and other raw materials

The existence of large uranium ore deposits in a country may influence the decision on the reactor type in favour of a type which can use the indigenous uranium directly without enrichment abroad. However, it should be recognized that the production of natural uranium fuel for a power reactor involves three manufacturing steps: recovery and milling of the ore, chemical conversion to high purity uranium dioxide, and fabrication into fuel elements and assemblies. Each of the three steps represents a manufacturing process with increasing complexity, tight specifications, and quality requirements which are difficult to meet without long experience and quality manufacturing tradition. The difficulties in fuel conversion and particularly fabrication should not be underestimated and it would in most cases be wise to plan for only a very gradual and slow introduction of these processes to achieve self-sufficiency for the fuel needed for a nuclear power programme.

For the reactors which need enriched uranium, industrial enrichment plants at the present time only exist in four Member States of the Agency (France, UK, USSR, and USA) and a pilot plant is operating in the Netherlands. Enrichment services in the future will also be offered by the two international groups URENCO and EURODIF. It must, however, again be emphasized that contracting for enrichment services can require very long lead times, even longer than the construction time for the nuclear power plant.

After use in the reactor both initially enriched and natural uranium fuels have a potential value because of the plutonium produced in them. This requires reprocessing in chemical plants which at the present exist as full scale or pilot plants only in ten Member States of IAEA (Argentina, France, Federal Republic of Germany, India, Japan, Spain, UK, USSR and USA and the International Eurochemic plant in Belgium). Only a few of these will offer commercial reprocessing services, and the plants are of a high degree of complexity. Initially enriched fuel will require reprocessing for economic reasons as the uranium is still slightly enriched, while spent natural uranium for some reactor types has been written off at no value and stored indefinitely at the power plant after use in the reactor. With high alternative energy prices it may well be economical to plan to store also initially enriched spent fuel for a long period of time and until reprocessing plants become more easily available. In this case it will be necessary to plan for a larger storage space at the reactor from the very beginning.

Before a decision in principle is taken to support a nuclear power programme with fuel cycle services based on either domestic natural uranium or enriched uranium, it is thus necessary to consider carefully, and without underestimation of the difficulties, the complexities and long-term perspective of a domestic fuel fabrication and other services. The Agency intends to publish a more detailed manual on this subject during 1975.

(d) Other considerations

Among the other factors, which should be taken into account in the choice of reactor type, are: The possibilities for local participation in the project, financing terms and training possibilities. A long-term perspective will help in considering these. If the first order is regarded to be only one in a series for essentially the same type of reactor plant (but possibly from different suppliers) it is clear that the possibilities of local participation seem likely to increase with each project and training can be established on a systematic basis. In this regard the nuclear power programme will be a potentially powerful tool for industrial development and domestic education of qualified engineers. On the other hand, very advantageous offers for financing of the first plant should not be allowed to carry too much influence in the decision on the long-term programme.

These considerations may eliminate certain reactor types from serious contention at an early stage. Therefore, the reactor type described in terms of the purchaser's requirements can be specified.

A choice of reactor type before bid invitations has a number of advantages. The bidding evaluation is easier, since a comparison can be made more uniformly. The bid documents will settle differences of opinion on type before the embarrassing situation arises of having to inform the bidder that his offer was rejected on grounds which were not of an economic nature. If agreement on a reactor type can be reached at this point, it is less likely that the purchase of a reactor will be postponed if the bids show that the lowest bid is for a type which is unacceptable for other reasons. Finally, an early selection of the reactor will make it possible to contract at this stage for enrichment services if they will be needed.

4.5. Proven reactor types

A number of power reactor types have been developed and brought at least to prototype operation. They can be broadly divided into gas-cooled, light-water and heavy-water systems and comprise the following main types:

(a) Gas-cooled systems

Magnox	Natural uranium fuelled graphite moderated gas cooled reactor. Used for the first stages of the UK and French programmes. Takes its name from the material (magnesium alloy) in which the uranium rods are canned.
AGR	Advanced gas cooled reactor. A UK development of the Magnox system using slightly enriched fuel in the form of uranium oxide clad in stainless steel.
HTGR	High-temperature gas cooled graphite moderated reactor. A further development of gas cooled reactors.

(b) Heavy-water systems

PHWR or CANDU	Pressurized heavy water reactors. Natural uranium fuelled, moderated and cooled by heavy water. (The Canadian design is called CANDU.)
HWLWR or SGHWR	Heavy water moderated boiling light water cooled reactor. (A UK design is called SGHWR — steam generating heavy water reactor.)
HWGCR	Heavy water moderated gas cooled reactors.

(c) Light-water systems

LWR	Light water reactors. Light water is both moderator and coolant. Enriched uranium is the fuel. This group includes two basic types:

a) BWR	Boiling water reactor. The coolant boils inside the reactor vessel.
b) PWR	Pressurized water reactor. The coolant does not boil inside the reactor vessel.
LWGR	Light water cooled, graphite moderated reactor.

This leaves out the fast breeder reactors. Although prototype fast breeders are in operation in France, the UK, USSR and USA, these still have developmental character and the fast breeder plants for commercial operation in the most advanced countries are not expected before 1985, which makes it unnecessary to consider them in this context.

In view of the relatively large number of commercial reactor types which have been developed and operated, it is worth while at this point to review the operating experience achieved to date on each type of reactor, with the objective of identifying those which are commercially available and would meet the criteria for provenness, such as those of the World Bank given in Section 4.4. From the standpoint of technology it is important to note that, except for the AGRs and the HTGRs, all the above reactors produce saturated steam of low temperature and pressure to drive the turbo-generators. The manufacture of turbines for these steam conditions initially encountered problems, principally because of their enormous size. However, turbines of this type are now being produced successfully in several countries and can be considered proven. The HTGRs and AGRs use conventional high pressure turbines which are also proven. Thus the new principles and technologies which should be evaluated in the context of suitability for developing countries are those associated with the nuclear reactor or the nuclear steam supply system. The extent to which each of these reactor types has performed is indicated in the following paragraphs.

(d) Magnox reactors

Although a large number of early Magnox installations (principally in the UK) have enjoyed a long record of successful commercial operation, and can definitely be considered proven according to the criteria given in Section 4.4, other types have proven more economic. The construction of new Magnox reactors has been abandoned, and they are no longer commercially available.

(e) Advanced gas cooled reactors (AGR)

The AGR is the successor of the Magnox gas cooled graphite moderated series of reactors in the UK. It differs from them mainly in the use of higher temperatures and pressures, and requires enriched fuels, resembling to some extent to the fuels used in light water reactors. The AGR 35 MW prototype at Windscale has been in operation since 1962 to explore the technological problems in depth. It has been a remarkable success, with availability increasing from 72% in 1963 to 95% in 1968. On the basis of this experience the UK Central Electricity Generating Board ordered in the late 1960s four AGR plants, each to have two reactors of 600-625 MW unit size, for commissioning between 1973-1977. The first AGR scheduled in this programme, Dungeness B, experienced severe delays of about three years in the construction and it will not be in service until 1975. The other plants have had less severe delays. The first full-scale AGR station to operate is Hinkley Point B which went critical in early 1974.

(f) High-temperature gas cooled reactors (HTGR)

Interest in the HTGR exists mainly in the USA, the UK, and the Federal Republic of Germany. The German experiment involves a 13.5 MW reactor which has been operating since 1966 at Jülich, and a 300 MW unit planned for operation in 1976. In the USA the 40 MW Peach Bottom reactor has been in operation since 1966, and a 330 MW unit at Fort St. Vrain has started operation early in 1974. Several commercial units in the 800 to 1500 MW range are being ordered by US utilities for operation in the 1980-1983 period. The HTGR follows the Magnox and AGR types as the third generation of gas cooled reactor technology. It will be some years before this reactor can be classified as a proven type according to the World Bank criteria.

(g) Pressurized heavy water reactors (PHWR — CANDU)

The first operating experience with a commercial version of the PHWR has been with the Douglas Point 220 MW CANDU plant which started operation in November 1966. Since its start-up, it has experienced a variety of problems. Modifications in design and construction have therefore been made both at Douglas Point and in the newer PHWR reactors, and it appears that the problems have been solved. The 4 × 510 MW Pickering units which were put into commercial operation during the period April 1971 to May 1973 have achieved capacity factors since their in-service date from 70% to 93%. On this basis, it must be concluded that the CANDU system is "proven" according to the World Bank criteria. Small PHWRs are also in operation in India, Pakistan, Sweden and the Federal Republic of Germany and larger units are being planned by Argentina; the source of supply for this type of reactor at present is limited to Canada. The ability of the PHWR to operate on natural uranium and the fact that it requires no large pressure vessel have made it attractive to many developing countries, especially those with resources of natural uranium.

(h) Heavy water moderated boiling light water cooled reactors (HWLWR, SGHWR)

The SGHWR is a light water cooled boiling water reactor designed and operated by the UK Atomic Energy Authority at Winfrith. A 100 MW prototype plant was commissioned in late 1967. It was afflicted at one time by a number of fuel element failures, but the cause of these has since been corrected and the plant has been giving satisfactory service with availabilities of the order of 90%. The Canadian AECL has built at Gentilly a 250 MW HWLWR. This plant, which started operation in 1970, is based on Canadian experience with heavy water reactors of the CANDU type, and the UK prototype. Though HWLWRs can operate on natural uranium, their economics improve if slightly enriched fuel is used, and the trend is towards this alternative. Commercial SGHWR designs of 450 MW and 600 MW have been prepared by UK manufacturers and offered to various countries, but no reactor of this size has been ordered yet and experience is thus too limited to consider it to be proven; however, the two units in operation have achieved very good availability. The UK has announced in July 1974 that it will base its future nuclear power programme on the SGHWR type of reactor and it can thus be expected to become a proven type in the future.

(i) Heavy water moderated gas cooled reactors (HWGCR)

Reactors of the HWGCR type have been in operation in France (80 MW) since 1966, and in Czechoslovakia (140 MW) and the Federal Republic of Germany (100 MW) since 1972. These reactors cannot be considered proven in larger sizes and there are at present no plans for construction of additional units.

(j) Light water reactors (LWR)

Operating experience with LWRs is certainly the most complete of any reactors now being offered commercially. Many utilities have reached the conclusion that in operation these nuclear power plants are at least as reliable as conventional ones. Though the prototypes were run one to five years before they reached a high standard of availability, more recent installations have usually required only one or two years, which is about the same "running in" period required for boilers of advanced design in large, conventional thermal plants. Performance has been satisfactory for the 600 MW to 800 MW plants representing the majority of those now in operation. Experience to date suggests that 70% to 75% plant load factor is a reasonable figure for system planning and economic calculations. No major technological changes in materials or in concept have been introduced in the most recent LWRs, but very large increases in size have occurred in a very short time, from plant of about 200-300 MW going into operation around 1962, to 600 MW around 1968, 800 MW in 1971-72 and 1000 MW in 1973. By 1 January 1974, light water nuclear plants had generated a total of 363 × 10^6 kWh of electricity,[4.1] testifying to the provenness of this type of reactor.

(k) Light water graphite moderated reactors (LWGR)

Reactors of this type have been in operation since the early 1960s in the United States and the USSR. In fact, the Hanford N reactor had generated more electricity by the end of 1973 (24 × 10^9 kWh) than any other single nuclear unit. In the USSR two plants of 100 and 200 MW have been in operation at Beloyarsk since 1963 and 1967 respectively. Despite this success, such reactors are not being offered commercially in the United States primarily because of their high capital cost. In the USSR, however, two large plants are under construction, each to have 2 × 1000 MW units for operation in 1975-76. To date, no LWGRs have been offered for sale on the international market.

[4.1] This is equivalent to meeting the entire 1971 electrical consumption of all developing countries of the world.

TABLE 4.1. CUMULATIVE GROSS NUCLEAR ELECTRICITY PRODUCTION BY THE MAJOR REACTOR SYSTEMS TO 1 JANUARY 1974

Reactor system	No. of reported power reactor units	Unit power range MW(e) (gross)	Cumulative energy production 10^6 kWh
Magnox	34	40 - 675	327 042
AGR	1	41	2 410
HTGR	1	46	1 190
CANDU	6	137 - 540	28 880
Other PHWR	2	12 - 57	2 130
SGHWR	1	100	2 370
HWGCR	1	73	7 550
LWR	57	55 - 1085	362 880
LWGR	1	862	23 870
		TOTAL	758 322

Note: This leaves out prototypes and some other reactors. The cumulative total nuclear generation by 1 January 1974 was 766 322 kWh in the market economy countries.

TABLE 4.2. REACTORS COMMERCIALLY OPERABLE AND UNDER CONSTRUCTION END 1973, CLASSIFIED BY TECHNOLOGY[a]

	Operable			Under construction or planned		
	No.	Net capacity MW	%	No.	Net capacity MW	%
Gas cooled						
Magnox	36	8 556	15.9	-	-	-
AGR	1	32	-	10	6 189	3.1
HTGR	1	40	-	8	6 054	3.1
Heavy water						
CANDU	9	2 640	4.9	10	4614	2.3
Light water						
PWR	39	25 539	47.3	119	110446	56.0
BWR	32	17 206	31.9	73	70 035	35.5
TOTAL	118	54 013	100.0	220	197338	100.0

[a] Excludes FBR, HWGCR, HWLWR and LWGR.

To give a general picture of the status of the various power reactor systems a summary has been made in Table 4.1 of the cumulative kWh produced by each system based on data in Nucleonics Week of 24 January 1974. The table is not complete as all power reactors have not been included due to lack of data but it clearly shows the tremendous experience gained with LWR and Magnox systems.

Another summary of power reactors in operation or under construction is given in Table 4.2.

It is clear from these two tables that, as the Magnox reactor is no longer commercially available for new plant construction, the light water reactors have had and have a dominant rôle in the nuclear power market, shared approximately equally between PWR and BWR reactors. For a proven power reactor the only remaining alternative is at the present time the CANDU heavy water reactor systems. Within some years the HTGR should also have reached the proven stage.

The proven reactors are, however, commercially available only in a size range which is essentially determined by the present requirements in the industrialized countries with their large electricity grids. This means a size for LWRs of between 440 and 1000 MW(e) and for CANDUs 500-600 MW(e), which, for system stability, is too large for many of the developing countries in which from a strict economic point of view, power reactors would now have been competitive in smaller sizes.

At present no commercial manufacturer is offering plants in sizes smaller than 440 MW(e) and if one were to be offered in the future, a buyer would have to raise the questions whether such a plant is proven by successful operation of a similar plant, and whether it can be shown to be licensable in an advanced country. A positive answer to both questions would be essential before it would be possible to advise a developing country to install such a unit. In this situation the IAEA has advised and continues to advise countries to purchase plants in the commercially available size range starting from 440-600 MW(e) for which a definite reference plant in the producer country can be given; but it is at the same time continuing its efforts to improve the availability of smaller, proven power reactors by showing the manufacturers the potential market for these plants.[4.2]

4.6. Domestic participation capabilities

The objective of nuclear power introduction has sometimes been described as independence from foreign energy sources. This is most often

---

[4.2] It must also be recognized that the sources of supply for the proven reactor systems are strictly limited. The design and manufacture for export of the CANDU type has only been carried out by Atomic Energy of Canada Ltd. Export orders have been or are being filled to four countries for CANDU reactors. LWRs can be purchased from four companies in the USA (General Electric for BWRs; Westinghouse, Combustion Engineering and Babcock and Wilcox for PWRs). Several European and Japanese companies also offer LWRs, most of them on licence agreements with US firms. Among these firms with past contracts are: Kraftwerk Union, FRG (PWR and BWR), Framatome and Schneider, France (PWR), Sogerca, France (BWR), Ansaldo, Italy (BWR), Mitsubishi, Japan (PWR), Hitachi and Toshiba, Japan (BWR), ASEA-ATOM, Sweden (BWR), and Brown Bovery, Switzerland (BWR and PWR). Technopromexport, USSR, offers a 440 MW(e) PWR unit. Of these companies and organizations only Kraftwerk Union, ASEA-ATOM, Technopromexport, General Electric and Westinghouse have so far received orders for export of LWR plants.

not achievable, except for very large countries with comprehensive nuclear programmes, and even then it is achievable only in the long-term and at a substantial initial cost.

The possibility of producing certain components and fuel for a nuclear plant may exist in some developing countries with well-established electrical and mechanical industries and an adequate supply of skilled labour. However, the initial costs for the introduction of new manufacturing processes and very strict standards and the initially uncertain volume of expected production may partially or fully offset cheaper wage rates. More important, perhaps, is the possible impact on the guarantees offered for performance of the first plant by the supplier. The net effect of these conflicting factors must be carefully analysed in the early stages of planning and reviewed again after a bid has been selected.

For the first nuclear plant, local construction labour will be used, including several categories of skilled labour, such as welders, who will have to be trained to work to higher standards than before. This will give definite benefits for the future development of skilled labour in the country and it may be a sufficient local participation in the first project. If a greater degree of participation is sought, it is necessary to make a careful survey and review of the domestic industry's capabilities before local participation is specified in bid documents. IAEA has helped to set up and carry out such surveys in the past. Experience indicates that it is a fair effort and requires qualified staff during at least six man-months for completion.

4.7. Pre-qualification bids

If doubts exist about the available power reactor types, sizes and their suppliers, it may be worth while to request pre-qualification bids from potential suppliers. Pre-qualification bids would also serve to indicate the interest of the individual suppliers to participate in a final bidding for the project and will help to provide a better basis for selection of reactor types.

The consultant should then prepare pre-qualification bid documents inviting all nuclear power plant suppliers to express their interest in submitting bids under the general terms and contract forms outlined and asking them to submit a considerable amount of technical information regarding their type of nuclear power plant and regarding their experience in manufacturing and procurement. The maximum sized plant which will be accepted for bidding should be stated. No prices or cost estimates should be requested at this time. The pre-qualification bids may give very valuable information about possible financing terms and scope of supply in the final bid. Through reference to plants in operation and under construction, these bids would also give definite information about each supplier's capability and experience.

Although it may appear as an unnecessary time delay in the realization of the first nuclear power project, the pre-qualification bid round is likely to provide so much valuable information about the sources of supply, technical characteristics, etc., that it is often a very worth-while enterprise, especially as site data collection and document preparation for the final bidding can go on during the time of the pre-qualification bidding.

5. PURCHASING THE FIRST NUCLEAR POWER PLANT

5.1. Definition of contract type and scopes

During the final stages of the pre-purchasing activities, the size and type of the plant have been determined and the sources of supply for the plant and its nuclear fuel have been limited to a number of pre-qualified suppliers. Possible sources of financing will also have been investigated. A major consideration in the decisions taken will have been the minimization of risk to the purchaser by choosing proven and to the extent possible standardized types and qualified suppliers. The utility now has to decide on how the power station will be purchased. Most of the background for this decision will have been acquired at the pre-purchasing stage, but the decision may be that some flexibility should be retained as long as possible and that the bidding documents should permit alternative scopes of supply for the nuclear power station. A decision is also involved on how the project management and particularly the construction management is to be organized and how the responsibilities, not only for the project work, but also to some extent for the final quality and reliability of the plant are to be shared.

The scopes of supply by the main reactor suppliers which have been offered are:

(i) Turnkey contract for the whole plant; and
(ii) Nuclear island (NI) or nuclear steam supply system (NSSS).

(a) Turnkey contract for the whole plant

In the turnkey contract, the bidder assumes overall project responsibility to supply and build a station which produces electricity in a specified time. Turnkey contracts still vary to some extent from contract to contract. Reactor plant suppliers have in the past often accepted the turnkey contract responsibility and hired an architect-engineering firm for design and construction supervision of the balance of the plant. In some European countries the reactor vendors still prefer to undertake the complete turnkey contract responsibility but in other countries this is not the case. Financing institutions have in some cases indicated a preference for separate purchases of the major plant systems (nuclear steam supply, turbo-generator, containment and other structures) with an architect-engineering or engineering-construction firm serving in an overall project management capacity and accepting essentially the turnkey contractor's responsibilities. In the latter case it is possible to ensure that competitive bidding on each one of the major systems is not limited but it requires an extremely experienced architect-engineering firm. From the buyer's point of view it should be equivalent if a reactor plant vendor or an architect-engineering firm acts as turnkey contractor as long as one of them would:

- Have complete responsibility for completing a working station within a scheduled time;
- Have complete responsibility for overall scheduling and all interfaces between different sub-contractors and equipment suppliers;
- Have overall responsibility for manufacturing and supply of the first fuel core starting at least from enriched UF_6;

- Give required warranties for the plant without conditions on supplies from other sources; and
- Have the responsibilities for quality controls for all equipment and installations.

Additional requirements can be placed on the turnkey contractor, such as use of local materials and training and use of local labour.

The turnkey type of contractor thus has very definite advantages but it is also necessary to recognize three potential disadvantages:

- If a reactor supplier is used as a turnkey contractor, it may, but should not necessarily, limit the possibilities for competitive bidding for major systems.
- As the turnkey contractor will have overall responsibility for the project management, the buyer may have little or no control over the job if special provisions have not been made from the beginning. This will finally require a high degree of trust between buyer and vendor.
- Under a turnkey contract it is the vendor who accepts most of the economic risk for delays and failures. This will most often be reflected in a higher cost for the whole plant, and it may limit the number of bidders for this type of contract in the future. Some of the reactor plant manufacturers already do not want to enter into turnkey contracts.

In summary, the turnkey technique is certainly advisable when little or no heavy construction experience exists in the country and when a large amount of training is required to attain the skills necessary. It is now also used in some places where qualifications and staff exist. The turnkey job has the advantage that it should provide a working power station, within the scheduled time, or with a minimum of delay, but it may have the disadvantage of a higher cost and that the buyer can exercise very little surveillance over the progress if appropriate terms have not been agreed to in the contract from the very beginning. Use of local production capabilities should be specified in a turnkey contract.

It has been pointed out before (Section 2.1) that the owner of a nuclear plant has specific responsibilities for the safety and reliability of the plant which he must exercise, for instance, by assuming the final responsibility for the effectiveness of a quality assurance programme during the design, manufacturing and construction stages. Part of this work, such as the supervision of quality controls, can be delegated by the buyer to an experienced firm of consultants or quality control engineers, but the original contract — and the bid documents — must make specific provisions for the exercise of this responsibility also for a turnkey contract.

(b) Nuclear island or nuclear steam supply system contract

Many utilities with nuclear construction experience and also most reactor plant vendors prefer to contract for the major systems of the plant separately, i.e. the nuclear steam supply system or nuclear island, which would also include the reactor containment system, turbo-generator, auxiliary systems and building structures. Each of the contractors would be responsible for the construction and installation of his system. This approach, of course, ensures competitive bidding separately for each system and a minimum overall contract cost but it also gives the buyer a greater responsibility than in the case of a turnkey contract and if experience does not exist the final costs may be higher. Besides the basic responsibilities for quality assurance and safety which in the case of separate system contracts will require a greater effort, the buyer will also have the responsibilities for design and construction interfaces between the systems and for co-ordination of the individual supply and construction schedules. He will have to provide the overall project management but on the other hand in this case he will exercise overall control over the project.

Purchasing by this technique has the advantage that the buyer can decide on his own to use local contractors and local construction skill in the areas where experience is available, while the nuclear steam supply (an area where the experience normally is not available) is still guaranteed by a foreign supplier. A drawback will be that warranties are likely to be limited in the way that each supplier only warrants performance of his own system and also makes it conditional on the other systems and there is no overall plant performance warranty. This disadvantage has in the past been avoided in some cases where the nuclear steam supply system vendor has taken over the responsibility for design interfaces and specifications for other systems and on this basis accepted to give overall plant performance warranties.

It follows that for the execution of this type of contract the buyer must have a much more extensive engineering organization and an experienced construction department or should have access to a competent private engineering-construction firm. This firm, which has to be experienced in the construction of large size conventional thermal stations, will cooperate with the nuclear steam supply contractor and will take the overall project responsibility. Since there will be several large firms operating on the job, communications problems, misunderstandings and some inefficiency are likely to arise, which have to be avoided to the extent possible by the buyer's project and construction management.

In order to choose the appropriate type of contract, the methods which have been employed in the past to construct thermal power stations and other large industrial projects (for instance refineries) give good indication of project capabilities within the country. If the capabilities are not very well developed, then the recommended alternative must be to buy turnkey, especially for the first project. Developing countries may attempt to use a nuclear power project for development in other areas (i.e. construction project management, industrial development) and write the bid invitation in a way that permits a number of alternative approaches, in the hope to gain an appreciation of how much the desired development will cost. This may be self-defeating, as it is finally the availability of skills and experience which must decide which type of contract should be chosen.

5.2 Bidding documents

It is likely that an experienced consultant will have been given the task to prepare the documents to be sent to prospective bidders. The following will only serve as an introduction to show the major effort which will have to go into the preparation of the bidding documents and it could also be used as a rough checklist in defining the scope of work for the consultants.

The general rule must be that bidding documents must contain enough information not only to allow the bidder to prepare an accurate bid but also to assure an easy and fair evaluation and comparison of the bids.

The bidder will spend of the order of several US $100 000 on the preparation of his bid and the buyer thus has at least a moral obligation to ensure that those efforts are not wasted by more or less arbitrary decisions on essential points in the evaluation, which in the final analysis may not serve his own economic interests.

(a) Background information

The bidding documents should contain a description of the studies and the assumptions which have led to the decision to request bids for a nuclear plant. If a programme of several plants is foreseen this should be indicated as should the needs and the plans for operating the first plant within this programme. The buyer should be very open to provide background information in order to avoid that the bidder makes his own – possibly inaccurate – assessment of the objectives.

(b) General project description

The general project description should include at least the data given in Annex 4, Part 1.

(c) Site characteristics

The site characteristics which should be described and documented are very extensive as discussed in Section 4.3 and Annex 4.

(d) Scope of supply

The type of contract preferred should be clearly stated (turnkey, nuclear island, nuclear steam supply system). It should be noted that even for a turnkey contract there are areas which may not be covered by a normal supplier's contract, for instance, site improvement, access roads, services, auxiliary buildings and structures (such as harbour piers, etc.) and it is important that the scope of the project should be clearly defined. The bidder must also be clearly informed about local regulatory licence or permit requirements and if he will be required to use a reference plant in his own country to document licensability of the proposed plant.

The buyer should describe the planned project organization including his quality assurance programme requirements and his procedures for approval and acceptance. The position of the supplier in relation to other contractors or consultants should be defined.

The bidding documents should also state how the first fuel loading is to be obtained and specify what the supplier's responsibilities will be.

(e) Evaluation methods

The bidding documents should state which methods and procedures will be used in evaluating and comparing the bids and give in details the cost breakdowns which are needed. In particular, the values placed on such factors as local supplies, foreign exchange and any special considerations such as training of local labour, and the development of local supplies may be stated. Stating this information from the beginning will give the bidder a possibility of commenting on the methods and procedures and it will also give him a possibility to make his bid in terms which are more favourable to the buyer according to the values and priorities he has established.

(f) General conditions

It is clearly advantageous if the buyer can supply a draft contract with the bid documents to give the bidder an understanding of the conditions under which he will be supposed to operate and also to obtain information about his exceptions or comments to these conditions. If the conditions are not clearly stated each bidder will supply his own draft contracts which may not be easily comparable.

Annex 4, Part 3, gives a partial list of the information which should be given as a minimum if a complete draft contract cannot be given. The list is not complete and the buyer should add to it based on experience from other projects.

(g) Financing

Financing of nuclear power projects has in the past often been obtained to a great extent through the supplier or from the supplier's country. If the commitment of a contract will depend on such financing, this should be stated.

5.3 Financing

From the point of view of a developing country, the nuclear power programme will be limited to a fairly small number of plants representing at best a small fraction of the total national investment allocations. For the supplying countries, on the other hand, there is often a desire to establish a foothold in exporting a new technology which may lead to granting loans for nuclear stations which would not otherwise have been approved for more conventional projects. International financing organizations may also pay special attention to projects with indirect benefits, such as diversification of sources of energy supply and they may devote resources to the financing of nuclear power over and above their established targets in the electric energy sector. It is worth while, therefore, to glance briefly at some typical terms of financing in the power field to illustrate the conditions which have been offered for nuclear and thermal power station projects. The information may be somewhat out of date in view of the present rapidly changing situation with regard to, for example, interest rates, and examples quoted are only intended to serve as illustrations.

Power plant financing usually involves an initial "grace period" during which no repayment of principal is required and interest may be either accumulated or paid currently. The grace period is usually equal to or somewhat greater than the construction period. In calculations it is normally assumed that "interest during construction" is accumulated and becomes a part of the initial capital investment to which the fixed-charge rate is applied.

IBRD[5.1] terms for (conventional) thermal power plants have for past projects been granting about a 3 to 5-year grace period, depending on the

---

[5.1] IBRD — International Bank for Reconstruction and Development (World Bank).

construction period, with a repayment period averaging 20 years; the interest rate has been about $7\frac{1}{4}\%$. (IBRD loans also carry a commitment charge on the undisbursed loan balance of 3/4 to 1%.)

Bilateral financing terms for power plants in developing countries have varied over a wide range, including some approximately as favourable as or even more favourable than IBRD terms. For example, in the case of KANUPP nuclear power plant in Pakistan, approximately half of the financing was by the Export Development Corporation of Canada under terms of 6% interest and 20 years maturity, and the remainder was by the Canadian International Development Agency under terms of 3/4% interest and 50 years maturity.

These data are given as examples only and it must be realized that they are unlikely to be typical of what can be obtained at the present time.

Provided the financing of a particular power project does not restrict financing of other projects, that is, that the financing of the project would be offered independently of other financing assistance to the country, a favourable financing plan may bring a substantial economic advantage to the recipient. At the same time, the competitive position of different alternatives may shift in favour of capital-intensive projects.

The extent of the advantage and of such a shift will have to be determined in each case by a complete present-worth analysis of each proposal and quick generalizations based on simplified models are, therefore, dangerous.

Nevertheless, it is instructive to assess, in very general terms, the potential impact of favourable financing on the competitive position of nuclear power plants, be it only as a guide for more precise discussion.

Without going into the extreme case where a nuclear plant would be supported by favourable financing while a conventional project would be given none, one may reasonably assume that bids for both projects contain identical financing terms for a given percentage of the total capital costs. Even in this case, however, the competitive position of the nuclear plant would improve, simply because relative equality of financial arrangements would imply a larger loan for the capital-intensive alternative.

The effect of favourable financing will be greatest when the capital cost differentials between nuclear and conventional stations are largest, that is, in the case of small and medium-sized plants. The conditions of independence for a particular project from total financing by the loaning agency are also likely to be more closely fulfilled for such plants since the total amounts involved will be relatively smaller.

There is, however, an inherent danger in generalizations from specific situations and the analyses of a specific project to the planning of nuclear power programmes for which the assumption of independence of nuclear power financing from total financing would be unrealistic. The planning authorities in developing countries will, however, have ample experience in this respect and will avoid this pitfall.

5.4 Warranties

A broad range of warranties have been offered by suppliers on plant and fuel performance and on workmanship and material. The situation is most clear in the case of a turnkey contract for which the performance warranty is usually given in terms of output (net or gross electrical and a net or gross heat rate) and the warranty is considered fulfilled if the output can be maintained for a specific period in the commissioning operation of the plant. The time period most often used seems to be 100 hours, but especially for turnkey contracts and also nuclear steam supply system contracts longer time periods, up to several months of test operation with warranted availability have been used. In addition to a penalty clause for not meeting the warranty output, this type of warranty often also carries a bonus clause for the supplier if the output can be exceeded. It is often fair to agree on a "dead band" around or over the warranty value within which neither penalty nor bonus would apply in order to reduce risks to both buyer and supplier. A turnkey contract would have corresponding warranties for project schedules. In the past these have in some cases proved of fairly small value to the buyers, especially if the maximum delay, beyond which penalties are not paid, is not backed up by provisions limiting the acceptance of delivery and in case of very extensive delays.

For nuclear island or nuclear steam supply system contracts, the performance warranties are of necessity more limited and given by different suppliers, under specific conditions from each one. It will, in such a case, be necessary to evaluate carefully which warranties should be requested and if they will constitute the optimum for the plant as a whole.

Warranties on workmanship and material are given against defects over a certain period of time of operation by the owner, usually one year, although longer period of up to two calendar or operating years have been used with renewed warranty of replaced or repaired equipment. The value of these warranties have often been questioned as they are for repairs or replacement only and penalties, if obtainable at all, are only symbolic and do not represent the true values of lost operation. The value of these warranties is impossible to assess in a bid evaluation.

From these considerations, it would appear that it is more realistic to request minimum, clearly specified warranties on performance and only a general warranty on workmanship and material. It is of importance to obtain the warranties from one supplier, which is, of course, most easily done for a turnkey project.

The question of fuel warranties is of necessity very complex as it will involve not only the first core supplied with the reactor but also subsequent reload fuel charges which will be mixed with older fuel in the core. As a general rule, it can be said that the stricter the warranties which are requested, the more limitations will be placed on the owner with respect to in-core fuel management, operation and a free choice of future fuel suppliers.

It is fairly normal, particularly for fuel delivered within a plant turnkey contract, to require a performance warranty on the fuel in the form of a minimum burn-up which the fuel should reach in the core. This already involves several problems. Present methods to calculate or measure the burn-up for individual fuel assemblies are not very accurate and, in addition, the continued burn-up of old fuel will, after partial refuelling of the core, be influenced by the characteristics of the new reload fuel. The warranties thus are — and have to be — normally restricted by the supplier to such an extent that they effectively may mean an obligation to purchase several of the reload cores from the first supplier.

The only way to avoid this is to build up a considerable in-house capability with the owner of the plant to perform in-core fuel management, set operational specifications, establish technical fuel specifications and exercise quality controls. This would permit the acceptance of warranties which are limited to mechanical tolerances and stability of the fuel assemblies.

Fuel warranties will be discussed more extensively in a supplementary manual on fuel supplies and procurement which IAEA hopes to issue in 1975.

5.5 Bid evaluation

The evaluation of the bids received is a major task and it will probably be necessary to obtain considerable help from the consultants who assisted in the preparation of the bidding documents. The following is intended to serve mainly as an outline of the tasks to be performed and an introduction to the procedures and methods to be used, assuming that the project group staff will participate to a maximum extent.

Much of the technical and economic evaluation work can be carried out by a team of engineers working in parallel. Technical deficiencies in the bid and other differences must be reflected as much as possible in terms of the financial currency being used for economic evaluation so that the evaluated bid prices can be adjusted to give a common basis of comparison.

The first task is to review the bids for responsiveness to the bid invitation document instructions. There is time then to draw the attention of the bidder to missing information.

This first review may indicate that certain questions were not properly understood by the bidders and task two will then be to correct deficiencies in the bids with the aid of the bidders.

The third task is a careful review of the scope of the work offered, to establish exactly what is offered and what is not, and particularly, the boundaries and conditions pertaining at the boundary points so that the balance of work can be determined. The fuel supply offers may be analysed for the same factors separately.

The fourth task is the detailed study of the work itself, to determine the quality and quantity of the equipment, material, labour and services being offered. The fuel supply may be analysed separately for these factors.

Since different persons will be involved, it is possible to separate from this work a fifth task: the study of the layout of the facilities proposed to determine ease of operation and maintenance, and of safety.

The final technical tasks are the evaluation of safety aspects of the plant and the overall plant performance, especially that of the nuclear reactor core.

The economic evaluation is based on the price quoted, on the terms of payments to the supplier and on the terms of the long-term loan which may be associated with the bid. In addition, the determination of the fuelling costs requires that long-term predictions be made of the cost of the components of this cost, usually for the plant lifetime. A good invitation to bid will have included the exact basis for calculating the unit energy costs. As indicated in Section 5.2 the exact procedure might have been provided to the bidders so that they can include their sample calculation in their bids and facilitate the understanding of them.

In the sections that follow, certain aspects of the technical evaluation tasks will be reviewed and the economic evaluation will be outlined. The latter will be the subject of a supplementary manual planned for publication by the IAEA in 1975.

(a) Technical evaluation

Task One: Responsiveness to bid invitation

An ideal bid will contain all of the information requested and draw careful and separate attention to all the exceptions taken. While it is possible to receive bids in which the exceptions are spelled out by the bidders, experience shows that most bids will not give all of the information requested. With the advent of increasing standardization, it will become less difficult to receive detailed descriptions of major components and systems, including drawings, diagrams and data sheets. For the present and, especially, for developing countries looking for nuclear power station units smaller than the units that are ordered in most of the developed countries, it will be necessary to review the bids for adequacy and clarity of the information given.

The main purpose of this first task is not to establish the adequacy of the equipment itself, since this is part of Task Four, but simply to establish whether the information is given on which it will be possible to base an assessment.

The same is true for the clarity and adequacy of the description of the engineering services to be provided – site supervision and commissioning supervision; design information, reference plant information, safety report, equipment and technical documents, operating and maintenance and commissioning manuals, construction and as-built drawings; and of quality controls and licensing support.

In general, Task One represents the first assessment of the quality of information offered in the bids. A list of deficiencies and shortages in the data should be prepared for possible early discussion with the bidders.

Task Two: Deficiencies in the bid invitation document

The work in Task One may show that certain information was not well understood by two or more bidders and that the bid invitation documents were not clear. It may be necessary to send out amendments to the bidders clarifying the uncertain points, correcting others and asking the bidders for an early response.

Task Three: Scope of work offered and its limits

Misunderstandings about the exact scope of work offered have caused many conflicts after contracts have been signed. Both parties must be absolutely clear, what is included and what is not included in the bid. The description of the scope of work should be included in the bid invitation document. However, many bidders will disregard this description and supply their own, or alternatively, while they may conform to the scope of work for the equipment requested, the scope of engineering services and of information to be furnished may differ from what has been requested.

There will be great variation in this task depending on the type of contract proposed by the buyer. A turnkey bid for the complete station may only involve the buyer in providing facilities and services to the site boundary and the limits of responsibility can readily be defined. A turnkey bid for a nuclear island requires much more careful definition of the interfaces of the equipment and of the engineering and labour services. A bid for a nuclear steam supply system requires considerable work in establishing the exact scope of supply and of the balance of plant.

Similarly, the scope of supply in the fuel bid requires careful study, especially as concerns the supply of complementary services in the first steps of fuel cycle before fuel element fabrication.

Task Four: Quality of the equipment and services

This review requires that the evaluators be knowledgeable concerning the type of equipment and the extent of services necessary. Some of the information will be directly available from the data sheets and other information provided in the bid. In other cases direct experience is needed to determine whether certain components, materials, procedures from certain suppliers are adequate to give reliable operation.

Where alternatives are proposed by a bidder, they must be evaluated to determine their suitability.

Of particular importance are the standards and quality controls proposed by the bidder.

Reliability of station operation will also depend on redundancy and adequate reserve stocks for items of equipment.

Evaluation of the quality of the fuel in terms of its performance in the core is also very difficult and requires expert knowledge.

Task Five: Station layout and equipment arrangement

Among the aspects to be checked are the adequacy of the arrangements for proper personnel movement including control zones, air locks, escape routes and for movement and transportation of equipment and of contaminated components; of the ventilation system under normal and accident cases; of protection against fire or flooding, of accessibility of components for maintenance and of water collection systems.

Of particular importance is a careful review of the ease of maintenance and repair work in the proposed design as this will be of great importance for the future operational availability of the plant. There have been examples of utilities in industrialized countries which have hired consultants to perform a separate review of maintainability due to its importance.

Task Six: Bid safety review

A separate review also has to be performed of how the safety aspects of the plant have been dealt with and how safety problems have been solved. Of particular importance is the comparative evaluation of the overall safety philosophy used in the design. Among the particular aspects which have to be reviewed are:

- The engineering codes and safety criteria which are to be used for the plant and how developments of these during the design and construction will be taken into account;

- How design input from site conditions, e.g. seismic data, flood data, etc., have been applied and the influence on costs of variations of this input;
- The capability and reliability of engineered safety features; and
- The results of the accident analyses, in particular for the reference accident, in the different bids have to be evaluated and for this the task group will have had to adopt suitable uniform evaluation methods.

The reference plants have to be clearly defined and the availability of all the needed design and licensing information on them must be assessed. Attention must be paid to the present status of the reference plants and how technology has developed since these plants were licensed.

This review of safety aspects will require a considerable effort as not only the bids have to be compared between each other but it will also involve a study of licensing requirements which have been posed on the reference plants.

Task Seven: Station performance

Some of the major items of plant performance will be included as proposed warranties in the bid invitation document. A turnkey bid will normally guarantee a net electric output, and a net station heat rate. The fuel performance warranty may be based on burn-up achievable. The ability to meet the warranted values must be carefully studied since the penalties may not cover the full cost of a shortfall in performance.

It is also necessary to perform an evaluation of the ability of the station to respond to changes in load (including step and ramp changes over a wide range) under normal and abnormal conditions and the behaviour and controls used for reactor and steam dumping if the turbine trips.

Of considerable importance is the evaluation of the refuelling and maintenance outage times, and of needed in-service surveillance, and securing inspection and tests during the plant's lifetime.

The fuel requires careful consideration, to determine the effect of operation at other than the planned capacity factor on refuelling scheduling and the effect on the fuel of operation under varying loads.

From the above short description of the technical evaluation it is clear that considerable experience and expertise is needed. The consultant who will advise in this work should have direct experience of the type of reactor in question, which by definition makes it almost impossible for any one consultant to compare very different reactor types in a consistent manner.

(b) Economic evaluation

The bidding document may have contained a specific request for financing proposals and an indication that the proposed financing scheme is to be treated as an integral part of the bid evaluation procedure.

The financing proposals of the bidders are then incorporated in the economic comparison of different tenders through methods which usually involve the following general steps.

(i) One or more present-worth discounting rates reflecting the time value of money and resources either in the economy as a whole or specifically in the power sector are assumed or imposed.

(ii) All items of revenue and expenditure (except the revenues accruing from the sale of power) are listed with a present-worth coefficient transforming their absolute values into their present-worth equivalents at a given reference date. Financing of different phases of the project is treated exactly in the same way as are other items, the amounts of money involved being counted as revenues when they are made available and as costs when they represent payments on interest or on principal. Thus, if a loan of US $1 is granted, it is counted as revenue at the time it is made available, and the payments on interest and principal as costs. If the present-worth total is smaller than US $1, the net result will be a positive net revenue which represents the grant element in the one dollar lent and which will be subtracted from the quoted cost of the financed item.

(iii) Corrections have to be made for the differences in the services expected to be rendered by the different alternatives (differences in size, availability and utilization factors, effects on the interconnected systems, etc.).

(iv) Subject to these corrections, the alternative with the lowest present-worth cost total is considered, at least from the standpoint of the above economic analysis, as the most advantageous.

The comprehensiveness of this method (present-worth analysis) and the ease with which it can produce summary figures and sensitive estimates with the use of relatively simple computer runs are likely to make it increasingly popular. Nevertheless, the inclusion of such financing terms as revenues and cost items does give rise to a series of questions, particularly the choice of a valid discounting rate. This is a problem which arises in any investment analysis, whether it is tied to outside financing or not, and there will be experience to base a particular choice on. The following three relevant points are mentioned only as a general indication:

(i) Theoretically at least, the present-worth role of discount represents a rate of return at which money can be obtained in unlimited amounts in the national economy or in a specific industrial sector.

(ii) In the present state of economic theory, there is no satisfactory way of computing this rate on the basis of general economic data and objectives so that its estimation always contains a large element of arbitrariness.

(iii) However, there are good, common sense reasons for developing countries to use a range of rates substantially higher than those prevailing in industrial states to reflect, not only their greater capital scarcity, but also the much larger profitability of their new investment projects which compete for limited financial resources.

The last observation underlines the significance of financing for developing countries. The availability of money at rates lower than the present-worth rate of discount appears to be equivalent to a rebate on the costs quoted by a supplier, and the procedure of economic comparison sketched in the introduction treats it exactly as such. It has to be stressed, however, that it is also necessary to take into account any possible total ceilings which may exist for loans to the country or the particular industrial sector and other competing projects before the possibly favourable terms for one given project are given too much weight.

The IAEA is developing a detailed manual for economic bid evaluation based on this method. It is necessary to base it on a detailed breakdown of costs and the Agency's manual will use the system of account presently employed in the USA, Japan and some other countries. The manual will also include a computer program to perform the present-worth calculations and the estimation of the levelized lifetime unit cost of energy which is the basis of the comparison of the bids.

5.6 Safety report and construction permit

When the supplier of the reactor plant has been selected it will be possible to prepare a preliminary safety analysis report for submission to the regulatory authority which in turn should issue the construction permit and finally the operating permit based on the final up-dated safety report upon conclusion of the construction. Normally the regulatory provision is that a construction permit cannot be issued until a complete review of the preliminary safety report which at present (1974) in some countries accounts for a delay of 1-2 years between the signature of the contract and the time construction may start. Figure 2.3 clearly shows that all effort must be made to have this review performed concurrent with contract negotiations and the early design stage, otherwise it may extend the overall time schedule. It has been recommended that for the first project in a developing country not only should the plant be of a proven type, but the supplier should also have the clear obligation to show that the plant is licensable in the country of the supplier. As the supplier country's regulatory authority would not make any statement about a plant built abroad, this will most probably be done through a reference plant built or being built in the supplier country. This would make it possible to supply the local regulatory authority with extensive safety information in the form of the safety analysis report for the reference plant at a very early stage in order to permit early familiarization with safety features and problems. This will facilitate the issuance of at least a conditional construction permit (Section 2.1 (b)), because the authority will already be familiar with many aspects of the preliminary safety analysis report when this is submitted.

The purchase contract should clearly state that the reactor plant supplier has to provide the safety analysis report under the contract, and only some chapters (over which the reactor supplier will still have the supervision), e.g. related to site data and operating organization are to be written by the project group. It is still necessary for the project staff to review the report in detail to ensure that it adequately meets the foreseeable regulatory requirements and, of course, that it is compatible with operational requirements.

It is also a basic responsibility of the reactor supplier to up-date the safety report during the whole design and construction of the plant to make sure that the final report, on which the operating permit is to be based, properly reflects the status of the plant as-built.

A reference plant, in the supplier's home country, can be used on which the supplier has to demonstrate licensability. To use this concept it is necessary that:

- All details of the reference plant design and all changes are known;
- The reference plant is so similar in size and design that any differences can be clearly defined;
- The reference plant is ahead in schedule but not too much, so that all licensing actions on it can be followed and that it still represents the most recent state of technology; and
- The details of licensing reviews and actions in the supplier country can be disclosed.

The use of a reference plant concept requires a considerable effort by the buyer as he will have to follow licensing actions and design changes on the reference plant in detail, which effectively means resident engineers in the supplier country, but this concept still saves effort compared to a complete and continuous safety review which will take up between 20 and 40 man-years. In view of the probable shortage of staff both in the project group and the regulatory authority, this method may be preferable, at least for a first project.

6. CONCLUSION

In this guidebook the steps and decisions towards a nuclear power programme have been covered in a general way up to negociation of the purchasing contract. The treatment has of necessity been superficial and it has not been the intention to give detailed information and recommendations at each stage but rather to draw the attention to major difficulties and problems which will be encountered. More detailed recommendations are given in referenced literature and in supplementary manuals which will be published in the near future.

By far the greatest problem which is likely to be encountered is the shortage of qualified staff for all the organizational units which are needed for the first project, and the need for forceful recruitment and training programmes for professional and engineering staff at all levels cannot be stressed enough. Recruitment must also be undertaken with sufficient lead times to permit training of staff for longer periods abroad. Compared to the very great capital outlays for the plant itself the early staffing costs are small and if the needs in the very beginning are recognized, these costs are an investment for the future plant operation which will pay very good dividends.

The maintenance of a highly skilled staff is likely to be a continuing problem. The nuclear power station staff will have obtained skills and experience which make it highly desirable in other industrial sectors and a high turnover of staff is likely. The training programme must thus be regarded as a continuing requirement for replacement staff and for requalification of staff which has been shifted within the organization.

Two other problems which are most likely to be encountered are requests to shorten the overall time schedule and the need for extra funds to meet various contingencies.

There are possibilities to shorten the time schedule of 11 years (Fig. 2.3), e.g. by exclusion of the pre-qualification bids round. Particular conditions in each country may also influence the overall schedule. Still, all exclusions or abbreviations are likely to lead to a loss of information

TABLE 6.1. INDICATIVE TABLE OF ASSISTANCE AND SERVICES FOR NUCLEAR POWER PROJECT AVAILABLE FROM IAEA

1. Clarifying the needs for a nuclear power programme
    - Nuclear Power Planning Study
    - Advice on legislative and regulatory framework
    - Advice on organizational structures
    - Advice on international safeguards requirements.

2. Preparing for the first nuclear power project
    - Fellowships for training of key staff
    - Experts to advise on setting up organizations and programme
    - Site surveys and advice on site data collection
    - Review of site report

3. Feasibility study
    - Advice on terms of reference for feasibility study
    - Review of feasibility study
    - Conduct of feasibility study as executing agency for a UNDP project

4. Pre-purchasing activities
    - Experts to advise on management
    - Review of pre-qualification bids
    - Surveys of local industrial participation capabilities, most often as UNDP project

5. Purchasing the first nuclear power plant
    - Advice on scope of supply and contents of bidding documents
    - Advice on evaluation of bids
    - Review of bid evaluation
    - Advice on content of preliminary safety report
    - Review on preliminary safety report
    - Advice on fuel supply and services as a fuel broker.

needed for important decisions, including, in particular, the decisions to issue site and construction permits, and therefore they contain an inherent element of risk which will finally always be borne by the plant owner. There are, on the contrary, many activities in Fig. 2.3 which may need more time than shown. Particularly the reviews before the issue of site and construction permits may well need longer times which in that case will extend the overall time schedule. Efforts to shorten the time schedule are thus not likely to be successful and it must be stressed that an orderly and logical approach to the decisions to be taken according to a realistic time schedule is more likely to give good results.

In several chapters the need to call in qualified outside assistance has been pointed out. This will add to the overall project budget, but even if the costs may be high in comparison with those experienced with conventional power projects in the past, they are still small in relation to the total project cost. There will be a continuing need for such extra funds also after the conclusion of the contract both for assistance from the outside, for instance for quality controls but, more importantly, to meet costs for changes which may be required as a result of safety reviews, changes and back-fitting in the reference plant, etc. Utilities which have built several nuclear power plants have learnt the need for contingency funds but for a first project adequate provisions may sometimes not have been made. The result of this will most often involve serious problems with the construction schedule.

A first nuclear power project will present new problems of technical, managerial and financial nature. In spite of available assistance from consulting firms, there will still be areas for which it may be desirable to call on an intergovernmental body, such as the IAEA, that will provide appropriate advice from a wider perspective. The IAEA would normally not give services which are available commercially. For ease of reference a summary of its normal assistance activities and services are summarized in Table 6.1. It is clear from this that IAEA's assistance to the plant owner may be extensive in the early stages and that it will understandably have to be limited to advice of a general nature and reviews of work performed by others in later stages. Assistance to the regulatory authority can be direct throughout the project, since there do not seem to be many commercially available alternatives at the present time.

It is planned to up-date this guidebook from time to time as needed. Comments would, therefore, be welcome and should be directed to

The Director
Division of Nuclear Power and Reactors
International Atomic Energy Agency
P.O. Box 590
A-1011 Vienna, Austria

ANNEX 1

ENERGY IN DEVELOPING COUNTRIES: SOME PROSPECTS OF FUTURE DEVELOPMENTS

R. KRYMM
International Atomic Energy Agency,
Vienna

The group of countries loosely defined as developing covers a wide spectrum of situations ranging from nations with subsistence economies to growing industrial giants. This heterogeneousness prevails sometimes within the borders of a single country with industrial poles wedged between largely unexploited areas. The only common denominator is the existence of large human and physical resources which are at present utilized substantially below their ultimate potential.[A1.1]

Among these resources, however, energy is one with which developing countries are exceptionally poorly endowed. If abstraction is made of a small group of Middle Eastern and North African countries, the developing countries, with a total population of 1.6×10^9 people, at present control less than 5% of the proven reserves of solid and liquid fuels, and less than 10% of those of uranium. Only in the case of hydro-electric energy is their situation favourable with more than two-thirds of the world's hydro potential on their territory. The technological status of solar energy utilization does not at present justify taking it into economic account.

This lack of domestic energy resources combined with a scarcity of investment funds has brought about certain special characteristics in the past structure of energy consumption in developing nations and is likely to channel their future growth along lines sharply different from those which marked the rise of industrial nations whose development rested on relatively abundant domestic supplies of energy and capital.

1. Some characteristic features of past energy consumption in developing countries

As Table A1.1 shows, the growth of total energy consumption was relatively buoyant in the 1950-1960 decade when it proceeded at a rate of 8.2% which was more than double that of the countries with market economies, though lower than that of centrally planned states. The rate of growth increased to an average of 7% over the 1960-1970 period resulting in a per capita consumption of about 360 kg of coal equivalent in 1970, a figure 17 times smaller than the 6160 kg consumed per capita in the market economies, and 6 times smaller than the world average of about 2000 kg.

[A1.1] The division of countries into developed and developing is like all socio-economic classifications fraught with arbitrariness and ambiguity. For the purposes of this article, the system used by the United Nations for aggregating statistical data on energy has been followed up to a point. This system divides the world into three major categories: 1) countries with developed market economies (Western European countries, USA, Canada, Japan, Australia, New Zealand, South Africa); 2) countries with centrally planned economies (USSR and all Eastern European Socialist countries as well as China and all Asian Socialist countries); 3) developing countries (all other countries). A further distinction was made in this paper between energy deficient and energy exporting developing countries, the latter being essentially defined as members of the Organization of Petroleum Exporting Countries.

TABLE A1.1. ENERGY CONSUMPTION (1950 - 1960 - 1970) (10^6 tons of coal equivalent)

	1950	Share (%)	Average annual growth rate (%)	1960	Share (%)	Average annual growth rate (%)	1970	
I. Developed market economies (North America, Western Europe, Japan, South Africa)								
Solid fuels	1100	56	-	1050	38.7	0	1100	24.5
Liquid fuels	500	25.5	6.6	950	35	7.9	2050	45.5
Natural gas	250	13	7.2	500	18.5	7.2	1000	22.2
Hydro and nuclear electricity	110	5.5	6.8	210	7.8	5.2	350	7.8
TOTAL	1960	100	3.3	2710	100	5.2	4500	100
II. Centrally planned economies (Europe and Asia)								
Solid fuels	420	81.4	10.1	1100	78.8	0.9	1200	59
Liquid fuels	77	15	9.5	190	13.6	9	450	22
Natural gas	12	2.3	20	75	5.4	15	310	15.3
Hydro and nuclear electricity	7	1.3	16	31	2.2	9.2	75	3.7
TOTAL	516	100	10.5	1396	100	3.9	2035	100
III. Developing countries (Africa, Asia, Latin America)								
Solid fuels	56	38.8	4.3	85	26.8	3.5	120	19.4
Liquid fuels	75	51.9	9.1	180	56.9	7	355	57.4
Natural gas	6	4.1	17.5	30	9.5	11.9	92	14.8
Hydro and nuclear electricity	7.5	5.2	11.1	21.5	6.8	9.2	52	8.4
TOTAL	144.5	100	8.2	316.5	100	7	619	100

Note: 1 ton coal equivalent = 7.10^6 Kilocalories.
1 kWh hydro or nuclear was assumed to be worth 2577 kilocalories throughout the 1950-1970 period.

Faced with a lack of domestic and foreign capital, the developing countries based their expansion on the source requiring a minimum of investment for production and for use, placing their primary reliance on oil which in many cases was imported in the form of oil-refined products. It is striking to note that liquid fuels accounted for more than 50% of their energy budget in 1950 when it represented about 25% of the total energy consumption of developed countries and that the share increased to 57% by 1970. The process continued up to 1973 with the percentage approaching 60%, putting the developing countries in a position particularly vulnerable to any drastic change in the terms of oil supply. Exactly this type of change occurred in the last quarter of 1973.

2. The immediate prospects (1974-1980)

In the last quarter of 1973, the tax paid costs of typical grade of crude petroleum in the main producing areas of the world were roughly quadrupled, rising for typical Iranian and Arabian light crudes from about US $1.85 to US $7 per barrel, or approximately from US $13 to more than US $50 per ton. In addition, revisions of participation agreements by the producing countries have led and are still leading to further increases so that an average price of US $8 to US $9 per barrel in the Persian Gulf is at present prevailing and chances of trend reversal in the immediate future are slight.

Even taking the minimal US $7 per barrel price, the oil deficient countries find themselves faced with an additional burden exceeding 10×10^9 US $ per year, an amount substantially larger than the sum total of all international assistance which they received in 1973, and in extreme cases, such as those of India, Bangladesh and Sri Lanka, threatening economic collapse. In all countries, however, regardless of the severity of the immediate impact an agonizing reappraisal of future energy development is taking place, both with regard to short- and long-term prospects.

Over the short term only limited means of coping with the crisis are available:

(a) A further cut in the rate of growth of energy consumption;
(b) International assistance for financing oil imports;
(c) An expansion of coal and lignite production whenever this is possible.

The first step would threaten the achievement of the very modest economic development targets of developing countries; the second would only be a palliative which in the best case would only last a few years; the third will be slow in operation and run into progressively more stringent physical limitations.

3. The medium term (1980-2000)

Among the major primary energy sources based on fully developed technologies, two offer special promise for developing countries: hydroelectric and nuclear energy. The first is the only primary energy source abundantly available in their territory; the second has such flexibility and economic advantages that in spite of the complexity of its technology

TABLE A1.2. ELECTRICITY CONSUMPTION (1950 - 1960 - 1970) (10^9 kWh)

	1950	Share in primary energy (%)	Average growth rate (%)	1960	Share in primary energy (%)	Average growth rate (%)	1970	Share in primary energy (%)
I. Developed market economies	692	13	9	1650	22.5	7.7	3475	28.5
II. Centrally planned economies	130	9	13.5	460	12.1	9.1	1100	20
III. Developing countries	53	13	9	125	14.5	10.4	335	20
WORLD TOTAL	875	12.4	9.8	2235	18.6	8.2	4910	25

it holds out the hope of gradually minimizing dependence on outside sources of supply. Both, however, are subject to a series of constraints which must be reviewed separately.

(a) Hydro-electric energy. Of the present hydro potential of the world estimated at about 23 × 10^{12} kWh for an average year, more than 25% lies in Africa, more than 20% in Latin America, and more than 15% in southeast Asia. Less than 2% of these potentials have as yet been harnessed and a reassessment of individual projects must be carried out. A glimpse of the economic advantages may be gleaned from the following considerations: With delivered fuel oil prices estimated at US $60 per ton, or 150 US cents per million kilocalories, a run-of-the-river hydro plant could be economic even if it involved an investment of a thousand US dollars more per kW(e) of installed capacity than its oil-fired counterpart.[A1.2] While reservoir hydro stations do not lend themselves to such simplified economic estimates their merits have also been substantially enhanced.

Under these conditions, a high rate of growth of hydro electricity production in developing countries is to be expected, but it will be subject to a series of constraints. Apart from the rather obvious availability limitations, the problems of transmission over large distances from potential sites, those of minimal project sizes and the frequent necessity of international agreements for the development of major river basins restrict the use of hydro energy both in space and in time, and, even in the regions where it is widely available, call for its combination with a more flexible source.

(b) Nuclear power. At first sight, the massive use of nuclear energy in developing countries might give rise to some doubts. Its technology is complex, initial investments in domestic and especially foreign currency are relatively high and, for the present at least, uranium resources are concentrated in the territories of industrial states. Nevertheless, the economic advantages of nuclear power over fossil-fired stations have become so evident that its penetration in developing countries is expected to accelerate sharply from the present very modest base. Again, using a simplified illustration based on the same assumptions as those made for hydro, and relatively high future projections for nuclear fuel costs,[A1.3] a nuclear power plant could cost from US $700 - 800 more per kW(e) than an oil-fired station and still be economic. Since the capital cost differential between the two types of stations in the 600 MW(e) range is less than US $300 per kW(e) the rate of return on additional investment could exceed 16%.

It should be added that under the above assumption the fuel costs of nuclear stations represent less than 30% of total electricity costs and the raw material component less than 13%, so that the sensitivity of total power costs to variations in uranium prices is less than one-fifth of that of electricity produced by oil-fired plants.

[A1.2] The assumptions are: constant 1974 prices, 10% rate of present-worth discount, 7000 hours annual utilization.

[A1.3] US $20 per lb of U_3O_8; US $50 per kg of separative work.

TABLE A1.3. PROJECTIONS OF ELECTRICITY CONSUMPTION IN ENERGY DEFICIENT DEVELOPING COUNTRIES (1970 - 2000) (10^9 kWh and 10^6 T.C.E.)

	1970	1980	1990	2000
10^9 kWh	320	832	2240	6000
10^6 T.C.E.	118	305	825	2210
Per cent of hydro and nuclear in total (%)	43	45	60	85

TABLE A1.4. PROJECTIONS OF ENERGY CONSUMPTION IN ENERGY DEFICIENT DEVELOPING COUNTRIES (1970 - 2000) (10^6 T.C.E.)

	1970	1980	1990	2000
Coal	120	200	340	550
Oil	320	530	825	1200
Natural gas	72	133	275	550
Nuclear and hydro electricity	53	137	495	1900
Other sources (solar, geothermal, tidal)			25	100
TOTAL	565	1000	1960	4300

Such decisive advantages must, however, be weighed against the constraints which arise from the complexity of the technology; the commercial unavailability of small nuclear power units more suitable to the interconnected systems in many developing countries and the necessity of financing the additional investment burden involved in initiating a nuclear power programme. If these constraints are removed by joint efforts of developed and developing countries there is no question that nuclear power will play a major role in the energy supply of the latter although its penetration will be gradual and begin with countries with relatively large electric grids and adequate training programmes.

In any event, both nuclear and hydro-electric projects require lead times ranging from 6 to 10 years between decision and completion so that a significant impact on energy supply structure from new projects can only be expected in the 1980s. Meanwhile, however, many developing countries have discontinued plans for oil-fired stations. A drop in the rate of growth of 10.4% which had prevailed between 1960 and 1970 for electricity consumption appears, therefore, inevitable for the present decade (Table A1.2). A resumption of the former growth rate beyond 1980 lies at the basis of Table A1.3 while the projections for Table A1.4, showing a discontinuous increase in the share of hydro-electric and nuclear electricity until it reaches 85% of total electric and 44% of total energy by the turn of the century, are derived from the assumption that after 1981 no oil-fired power stations for base load duty will be built except in very special circumstances.

4. Conclusions

Any generalization on the future energy growth of developing countries considered as a whole is, of course, a highly simplified abstraction and projections can only be based on the aggregation of results obtained for each country considered individually and in detail. The very tentative estimates contained in Table A1.4 must, therefore, be taken as no more than the outlines of a possible scenario resting on the fulfilment of several crucial assumptions, chief among which is that the developing countries will receive both the immediate assistance which will permit them to bridge the present oil crisis and the financing means which will help them implement optimal long-term solutions.

If these rather optimistic assumptions are fulfilled, the very modest results embodied in Table A1.4 will be achieved at minimal total costs. They show a resumption of total energy consumption growth rates from the deflated level of less than 6% in the 1970-1980 period to 7% and 8% for the next two decades leading by the year 2000 to an annual energy consumption of 4.3×10^9 tons of coal equivalent, and to an average per capita consumption of 1200 kg per year for each of the 3.55×10^9 inhabitants of developing countries at that time. When these figures are viewed against the 28×10^9 tons of coal equivalent, the estimated figure for the world total consumption of energy by the turn of the century, and against the 4.4 tons of coal equivalent per capita world average, it will be seen that the gap will only have narrowed but will still be far from closed.

LEGISLATIVE FRAMEWORK AND REGULATORY REQUIREMENTS FOR THE INTRODUCTION OF NUCLEAR POWER

HA VINH PHUONG
International Atomic Energy Agency,
Vienna

1. INTRODUCTION

The whole process of introducing nuclear power usually requires the state concerned to start planning and making preparations nearly a decade before a nuclear power plant is to go into operation. In preparation for this work, the IAEA technical assistance programme and advisory services are increasingly utilized by Member States for the provision of expert services and the training of personnel as well as for the elaboration of adequate legislation to govern the licensing of nuclear facilities.

Amongst the preparatory steps required for the implementation of a nuclear power programme, it is essential that consideration be given at the earliest stage to the legal and administrative aspects thereof in order to achieve a timely setting up of an adequate legal framework and infrastructure within which the execution of nuclear power projects is to be made, subject to appropriate authorization, coordination, control and supervision. The legislation governing industrial establishments of a hazardous nature and, in particular, public utilities will, of course, have to apply to the erection of nuclear power stations as well. However, the most stringent safety measures required for nuclear installations because of the special nature of atomic energy, and the effective financial protection to be ensured for victims of a nuclear incident add new dimensions to traditional patterns of regulatory schemes devised for industrial activities of a conventional type. Consequently, special legislation dealing with nuclear facilities is essential and its primary objectives should be:

(1) To provide a regulatory basis for securing a reasonable assurance that nuclear installations can be constructed and operated without undue risk to the public health and safety, and without harm to the environment; and
(2) To ensure adequate financial protection for third parties in the event of a nuclear incident, in view of the potential magnitude of damage and injury which may arise from such an occurrence.

The main components of a nuclear licensing system, therefore, consist of (a) a set of basic provisions setting forth the fundamental safety principles, criteria and conditions for the prior authorization, control and supervision, by an established authority, of the construction and operation of nuclear facilities; and (b) a set of liability provisions to regulate compensation for nuclear damage and financial security therefor.

2. REGULATORY BASIS FOR NUCLEAR LICENSING AND ADMINISTRATIVE ASPECTS

2.1. Enabling provisions

In some countries, the basis for the licensing of nuclear facilities may be found in the act creating a national authority on atomic energy and vesting it with broad powers. By virtue of such powers, the competent authority would merely have to establish such regulatory schemes as required for implementing the basic provisions of the enabling law with respect to nuclear power projects. In other countries, where a legal framework for nuclear activities has not been enacted or is not broad enough to provide a basis for the establishment of a reactor licensing system, it will be necessary to prepare legislation comprehensive enough to embrace both the regulatory and liability aspects of a nuclear power programme and, also, vesting sufficient discretion in a competent authority for dealing with regulatory and procedural matters.

The main provisions of a licensing act would usually define the objectives and scope of the regulatory requirements; establish or determine the competent authority in the licensing process, its powers and duties; provide for the setting up of technical advisory bodies; and specify the qualifications and conditions to be fulfilled by an applicant, the information and documentation to be submitted by him, a phasing of the safety assessment and reviews by the licensing authority, the conditions under which the latter may grant, amend, suspend or revoke a licence, and the obligations resulting therefrom for the licensee. Through a sequence of siting approval, construction and operation permits under a regulatory scheme for reactor licensing, the primary objective is to subject each site and plant to a safety review in depth to determine the extent to which siting and safety criteria are satisfied or siting should be reconsidered, or modifications to the design, construction or operation of the plant are deemed necessary, in the interests of public health and safety as well as for protection of the environment. Moreover, by means of inspection, the licensing authority should be in a position to supervise every turn in the implementation of a nuclear power project.

In this connection, it appears desirable to entrust the licensing authority with powers broad enough to enable it, with the advice of specialized bodies, to formulate and issue safety regulations and rules as needed. Thus, the operational standards and technical requirements embodied in licensing regulations could be more readily responsive than the principle provisions of a law to technical developments and other changes; their revision could be more easily undertaken without involving a lengthy process of parliamentary approval.

2.2. Licensing regulations and procedures

On the basis of enabling provisions as may be available in existing legislation or to be enacted for the establishment of a nuclear licensing system, the preparation of licensing regulations, detailed operational standards, operating guides or codes of practice is to be given special attention by the licensing authority or the authority proposed to perform such function. A practical way of tackling this important task is to make the fullest use of the IAEA safety standards and guides available in a large number of publications, many of which have been issued in the Agency's Safety Series jointly with other international organizations. Particular reference is in this context made to a guide on Organization of Regulatory Activities for Nuclear Reactors.[A2.1]

In the elaboration as well as at the stage of implementing licensing regulations and procedures, it is deemed advisable that the licensing authority be assisted by technical advisory bodies fully representative of various ministries, State agencies, specialized associations and other institutions as appropriate, which either have statutory responsibilities for or are qualified in one or more aspects of a nuclear power programme. Such an inter-ministerial, inter-agency and multi-disciplinary approach to the issues involved in the licensing process would ensure that qualified advice from those having a part to play in nuclear power development would be available to the licensing authority on a standing basis, in the formulation of regulations and rules as well as for their implementation. Moreover, through such advisory bodies, the licensing authority would be in a position to carry out its regulatory functions in full understanding of the views and requirements and with the effective cooperation of those concerned while the ultimate responsibility for regulatory matters would rest with it.

Detailed operating instructions and procedures should be drawn up by the utility in keeping with the technical limits and conditions proposed by it for approval by the licensing authority. Any change in the limits and conditions specified for the plant as well as any modification affecting the approved design of the plant should be subject to review by the licensing authority to assess their relevance to the plant safety. Similarly, any deviation from the limits and conditions as well as equipment failures with a bearing on the plant safety should be reported to and assessed by the licensing authority with a view to corrective action by the utility as necessary.

The utility should maintain records of all essential information concerning the design and operation of the plant and of the amount and movement of all nuclear material; such records should be available to the licensing authority, to whom the utility should also supply reports on specified matters.

2.3. Licensing responsibilities and organizational aspects

The regulation of nuclear power development implies Government action to ensure that the safety criteria, standards and conditions required by the special nature of this source of energy are effectively reflected in the design, construction and operation of a nuclear plant. In the Agency's Code of Practice for the Safe Operation of Nuclear Power Plants (Safety Series No.31, IAEA, Vienna (1969)), it is recommended that (Section 1.3):

> "In discharging its responsibility for public health and safety, the Government should ensure that the operational safety of a nuclear reactor is subject to surveillance by a regulatory body independent of the operating organization."

[A2.1] INTERNATIONAL ATOMIC ENERGY AGENCY, Organization of Regulatory Activities for Nuclear Reactors, Technical Reports Series No.153, IAEA, Vienna (1974).

Consistent in a broad sense with this recommendation and, also, in line with a current trend in a number of countries, the separation of regulatory responsibilities from development functions appears desirable in regard to nuclear power projects. In this context, the statutory powers of a regulatory body or licensing authority would cover two main areas:

(a) Establishment of nuclear safety criteria, standards, guides and rules for the licensing of nuclear facilities, and issue of licences for such installations; and
(b) Inspections and audits to determine operational compliance.

Proper organization of the licensing authority for the discharge of its functions in respect of safety assessment and inspection is of paramount importance in the interests of nuclear safety and public acceptance of nuclear power plants. Irrespective of whether the licensing authority has already been established or would still have to be determined by law, that body should not rely solely on the ability and reliability of the operating organization or contractors thereof with regard to the safety assessment and reviews called for under the licensing process in action. Moreover, prior to such activities, the regulatory body must also carry out its very important role of standards-setting and rule-making and, to this end, should keep itself abreast of relevant literature, available international standards and recommendations, current safety criteria, guides and practices of other countries as well as latest developments in control techniques and instrumentation.

Therefore, the licensing authority should have a number of positions of a specialist nature with a view to a staff well balanced in the main aspects of nuclear safety. Its staff should, for instance, be knowledgeable in such fields as: health physics, radiological health, radiochemistry, nuclear physics, reactor operations, chemical, civil, electrical, mechanical, nuclear engineering. In most cases, it would be useful for such personnel to undertake overseas training in the preparatory phase, through bilateral arrangements with other countries or through the channel and with the help of international organizations.

In view of a prevailing trend in developing countries with respect to power supply which is generally the responsibility of state-owned corporations or public undertakings – and since, in many respects, the installation of a nuclear power station may be considered as a normal extension of the work of such corporations, there appears to be no need for setting up a separate organization to deal specifically with nuclear power projects in such given situations. In other words, the development of nuclear power may be considered as falling within the scope of the statutory activities of the organization responsible for electricity generation in the country. However, on account of the expertise required in the broad aspects of power reactor technology and in specialist areas such as plant evaluation and costing, core performance, instrumentation and control, reliability engineering, quality assurance, it is necessary to establish within the Power Department, the Electricity Generating Authority or the Public Utilities Board, and at an early stage in the planning for nuclear power, a group of specialists who should initiate the groundwork in preparation for the discharge by the Authority or the Board in question of its development and implementation functions. These functions cover broad areas such as the collection of data and the performance of various studies needed for site selection, preliminary investigations for the feasibility study, costs estimates, preparation of specifications for tendering, bids evaluation, preparation of safety documents for licensing purposes, quality assurance at successive stages in construction and operation, fuel supply and management, reactor operation, accountability for and physical protection of nuclear material. As in the case of the staff required for the Regulatory Body, appropriate training of the utility's personnel assigned to specialist areas is to be given high priority in the preparatory phase. However, on the assumption that outside consultants services could be used for carrying out many of the above tasks, the requirements for technical personnel need not be contemplated in the early stages in a too ambitious way.

3. LIABILITY PROVISIONS FOR NUCLEAR INSTALLATIONS

Inasmuch as a regulatory scheme for ensuring the safety of nuclear installations is a prerequisite to introducing nuclear power, the regulation of nuclear liability and financial security therefor forms an essential component of a comprehensive nuclear licensing system. Victims of a nuclear incident should be provided with adequate compensation to be secured by law which, concurrently, should not expose the nuclear industry to unbearable burdens. A balance of these considerations, which has led to a compromise between acceptable risks associated with and the benefits expected from nuclear activities for the community, is reflected in the special regime of liability for nuclear damage. The principles of such liability as developed at the international level in the last decade to cope with a new technology and as embodied in a number of international conventions[A2.2] have found their way into many national laws. They primarily provide for:

- The channelling of liability to the operator of a nuclear installation, whose liability is absolute (or objective), irrespective of fault;
- A limitation in amount and in time of the operator's liability, and the obligation for him to maintain financial security up to the established liability limit, either by insurance or other financial means; and
- A single court competent and one law applicable to all claims resulting from a nuclear incident.

Under this regime of liability, the operator, i.e. the licensee or holder of the permits, is exclusively liable for all damage caused by a nuclear occurrence in his installation or involving nuclear material in the course of transport to or from his installation. Accordingly, judicial proceedings would be much simplified for a victim in seeking compensation for nuclear damage. Also, the operator's strict liability, in relieving his

---

[A2.2] Information on the status of international conventions on third party liability for nuclear damage is available upon request to the Legal Division, International Atomic Energy Agency.

suppliers from liability claims, would lead to a reduction of insurance or other financial securities and, consequently, of the overall cost of a nuclear installation. Their contractual arrangements may thus be simplified to a great extent.

4. CONCLUSIONS

In view of the time generally needed in the law-making process under any given legal system – usually a year – especially when the framing of laws and regulations is confronted with the necessity of harmonizing overlapping responsibilities within a national administration, with the desirability of attaining an optimum balance of promotional interests and safety consideration, and with relatively new legal schemes such as those required for the development of nuclear energy, the elaboration of legislation should preferably start at the earliest possible stage in the planning of a nuclear power programme. The object of an early consideration of the organizational, regulatory and liability aspects of a nuclear licensing system is to clear the necessary but time-consuming rule-making process so that there is minimal delay when the authorities decide to authorize the implementation of a nuclear power project. Safety assessment need not become a roadblock to technological progress; used adequately, it should be a valuable component in the decision-making process for nuclear facilities.

The adoption of a concerted approach to the tasks involved would facilitate the integrated use of many related sciences and disciplines as well as an effective collaboration between various departments, agencies and institutions concerned, in the formulation of policy decisions, the establishment of regulations, and throughout the licensing process. And this, in turn, will pave the way for public acceptance of nuclear installations.

ANNEX 3

IAEA'S SUPPLY OF NUCLEAR FUEL AND REACTORS

O. PEDERSEN
International Atomic Energy Agency,
Vienna

STATUTORY BASIS FOR AGENCY SUPPLY

One of the Agency's functions is that of a broker or intermediary between its Member States in the transfer of enriched uranium, enrichment services, plutonium, and reactors. It is, in fact, the first of the Agency's functions in the order listed in its Statute. Article III.A.1. on the Agency's functions authorizes it, "if requested to do so, to act as an intermediary, for the purpose of securing the supply of materials, equipment or facilities by one Member of the Agency for another". Under Article IX, a Member may make special fissionable materials available to the Agency and the Agency may receive and allocate them to other Members. The Agency may take and maintain physical possession of these materials, but has in practice so far not done so. Articles XI, XII and XIII indicate the procedure, and outline the basic terms and conditions on which international transfers of special fissionable and other materials, services, equipment, and facilities can take place through the Agency.

AVAILABILITY OF NUCLEAR FUEL AND REACTORS THROUGH THE AGENCY

Nuclear fuel

At present four Member States of the Agency – France, the Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland and the United States of America – have government-owned plants for enriching uranium. The provision of enriched uranium or enrichment services from these plants is arranged through governmental channels, either directly between the supplying and recipient states, or through the Agency, acting as an intermediary between the two states concerned.[A3.1]

In 1957, when the Agency's Statute entered into force, the Soviet Union, the United Kingdom and the United States offered under Article IX.A of the Statute to make uranium enriched in the isotope uranium-235 available

---

[A3.1] In addition, nuclear fuel can be bought directly from two international groups, URENCO-CENTEC and EURODIF. They began in 1973 to make commitments for future uranium enrichment services. URENCO and CENTEC are two closely connected international companies established under the Almelo Agreement, ratified on 19 July 1973, between the Governments of the Federal Republic of Germany, the Netherlands, and the United Kingdom. They both have British, Dutch and German shareholders and have a joint chief executive. URENCO supplies uranium enrichment services from centrifuge plants developed and supplied by CENTEC. EURODIF is an international group in which the Governments of Belgium, France, Spain and Italy participate. It is constructing in France a plant for separation of uranium isotopes based on French diffusion technology.

to the Agency. Later the United States also offered small quantities of uranium-233 and plutonium. The quantities were as follows:

Member		Quantity (kg)
Soviet Union	^{235}U contained in enriched uranium	50
United Kingdom	^{235}U contained in enriched uranium	20
United States	^{235}U contained in enriched uranium	5070
	^{233}U	0.5
	^{239}Pu	3

The terms and conditions for the international transfer of the material thus made available to the Agency are set forth in the agreements concluded by the Agency with each of the three Governments on 11 May 1959.[A3.2] The agreement with the United States was amended in 1974.[A3.3]

The duration of these agreements differs. The one concluded with the Soviet Union "shall cease to have effect one year after the day of its denunciation by the Agency or the Government", while the one concluded with the United Kingdom will remain in force "until the end of any calendar year after 1960 in which notice of the withdrawal of the offer has been made".

The agreement with the United States was originally concluded for a period of twenty years, which would end in 1979, but the amendment in 1974 extended it until the year 2014 and the United States undertakes to make also available to the Agency, from time to time, such additional quantities of materials as may be authorized by the United States legislation. This will allow for the possible supply of nuclear fuel to Member States through the Agency during the expected lifetime of the current generation of power reactors. The amendment also stipulates that this duration may be further extended by agreement between the parties. In this connection, it is to be noted that the United States authorities have in 1973 published new criteria for uranium enrichment services.[A3.4] These criteria make it clear that the obligation of the USAEC to furnish such services can result only from the conclusion of a specific contract in each case. The United States authorities have nevertheless assured the Agency that the new criteria will not affect the undertaking given by the United States in the agreement to make available to the Agency the quantity of contained uranium-235 mentioned above.

The provisions in the agreements regarding prices are as follows:

(1) Soviet Union: "The Government undertakes to base prices on a scale of charges corresponding to the lowest international prices in effect at the time of delivery for enriched uranium hexafluoride and for uranium compounds according to the percentage content of uranium-235";

[A3.2] The texts of the agreements are reproduced in Agency document INFCIRC/5.

[A3.3] The amendments, which entered into force on 31 May 1974, will be reproduced in Agency document INFCIRC/5/Add.1.

[A3.4] United States Federal Register, 38 F.R. 1280, 9 May 1973.

(2) United Kingdom: "The material shall be supplied at a price and on conditions which are not less favourable than the most favourable price and conditions which the United Kingdom Atomic Energy Authority are offering or are prepared to offer, at the date of the contract in question, to any other customer outside the United Kingdom for the supply of similar material"; and

(3) United States: The policy of the United States is to make special nuclear material available to the Agency at the United States Atomic Energy Commission's published charges applicable to the domestic United States distribution of such material in effect at the time of transfer. This policy remains unchanged. However, a specific provision embodying this policy has not been included in the agreement as amended in 1974, since the United States Atomic Energy Commission was not able to guarantee for the duration of the agreement, as extended until the year 2014 by the same amendment, that material can be made available through the Agency at charges applicable to its domestic distribution.

Reactors

Reactors or reactor components are normally transferred between Member States on a bilateral basis. However, the Agency's Statute enables it to act as an intermediary in the supply of such facilities and equipments. Also, the United States has in the above-mentioned agreement with the Agency undertaken to permit the transfer of reactors and reactor components through the Agency for Agency assisted projects. Pursuant to this agreement the United States has in 1974 agreed to transfer components for three power reactors through the Agency, two to Mexico and one to Yugoslavia. The use of the Agency as an intermediary obviates the need for negotiating and concluding a bilateral co-operation agreement between the United States and the country concerned. In addition, two training reactors had previously been transferred through the Agency to Argentina and Mexico respectively as gifts from the Federal Republic of Germany.

PROCEDURE FOR SUPPLY OF NUCLEAR FUEL AND REACTORS THROUGH THE AGENCY

Under the agreements with the three supplying Member States mentioned earlier, the latter have undertaken to make materials available to the Agency on request. The procedure to follow in order to enable the Agency to transfer such materials to other Member States, upon request, is outlined below.

Requests

Any Member or group of Members desiring to set up a project for the peaceful use of nuclear energy may request the Agency's assistance in securing special fissionable and other materials, services, equipment, and facilities necessary for this purpose. The request must be accompanied by an explanation of the project and must be considered by the Agency's Board of Governors. Article XI.E lists certain matters to which the Board has to give due consideration before approving the Agency's assistance for the project; among the factors involved, the usefulness as well as the scientific and technical feasibility of the project are mentioned in the first place.

On the basis of the information provided, the Agency's Secretariat analyses the request. The request and the Secretariat's conclusions thereon are presented as early as possible to the Board. The Board's consideration of such requests has usually been very brief and the Board generally endorses the recommendations presented by the Secretariat.

In 1968 the Board approved a simplified procedure for the supply of small quantities of nuclear materials for research and development or for use in neutron sources. Under this procedure the Director General is authorized to arrange for the supply of such research quantities of material under appropriate agreements without prior approval by the Board which is informed of such transfers by means of the Director General's periodic reports.

Choice of supplier

As the Agency, although authorized to do so by its Statute, does not keep its own stocks of nuclear materials, a supplier of the material has to be selected. In choosing the supplier, the wishes of the requesting Government are taken into consideration in accordance with Article XI.C of the Statute. If the requesting Government does not express a preference in this regard, enquiries are addressed by the Agency to Member States likely to have the material or enrichment services required. However, the country from which the material could be obtained may not be the one where the material is to be processed into the required chemical and physical form, and such situations would have to be dealt with on a case-by-case basis in accordance with the wishes of the Government setting up the project.

Agreements

Before the material can be supplied through the Agency, two agreements have to be concluded. One of these is known as the Project Agreement, to which the recipient Government and the Agency are parties; it is required by Article XI.F of the Statute, where most of the points to be covered are set forth. Of particular importance are the statutory requirements that the project be subject to safeguards and to applicable health and safety standards; provisions relating thereto are specified in the Project Agreement whose structure and contents have been largely standardized over the years and vary only to meet particular circumstances.

The other agreement is known as the Supply Agreement, which is a tripartite agreement between the Agency, the supplying State and the recipient State, and in which the exact type and quantity of the material to be supplied, as well as the terms and conditions of supply, are specified.

Terms and conditions

The terms and conditions of supply to the recipient Government, including the price of the material, are normally the same as those offered by the supplying Government. The Agency's services are thus provided free of charge.

In exceptional cases, the material itself has been provided free of charge by the supplying Government, but never for power reactors. The main example of material provided free of charge is the annual gift of US $50 000 worth of special fissionable materials made since 1960 by the United States Atomic Energy Commission to the Agency to assist and encourage research on peaceful uses of atomic energy or for medical purposes. The charges for fabrication of the material into the desired form and the transport agreements are, however, to be paid by the recipient Government. Another example of gifts from Member States in connection with Agency-assisted projects is the donation by the Federal Republic of Germany of two training reactors to Argentina and Mexico as mentioned earlier.

CONCLUSION

The Agency's function as an intermediary or broker between Member States supplying and requesting materials, equipment or facilities depends entirely on requests for the Agency's services by Member States. The implementation of this function, therefore, is entirely dependent upon Member States' interest in it.

Contrary to the expectation of the founders of the Agency, Member States have so far generally preferred bilateral arrangements. Nevertheless, some Member States have found that the transfer arrangements the Agency is able to make offer them opportunities of obtaining materials which would not otherwise be directly available to them. Other Member States, wishing to obtain long-term supplies of enrichment services for their nuclear power plant, seem to favour supply arrangements through the international channel provided by the Agency instead of bilateral supply agreements with a single supplying state.

However, to date most transactions only related to research reactor fuel or research quantities of material. The first requests to the Agency to act as intermediary in the provision of enrichment services and reactor components for full-scale power reactors came from Mexico (two units) and Yugoslavia (one unit) and were approved in 1974.[A3.5] The changing supply situation and the expansion of nuclear power programmes, as well as possible reluctance to depend overly on only one supplier, may bring other countries to follow this approach.

At the Agency's XVIIth General Conference in September 1973, the Director General pointed out that most States with nuclear programmes must concern themselves with future supplies of enriched uranium. He urgently appealed to present and potential suppliers to make available sufficient quantities of material for power reactors for transfer to developing countries through the Agency under less stringent conditions than those obtaining currently.

In conclusion, it can be said that the enriched uranium and enrichment services made available to the Agency by supplying Member States have so far been sufficient to meet demands, and there is every reason to believe

---

[A3.5] The texts of the agreements concerning the Agency's assistance to Mexico for the Nuclear Power Plant of Laguna Verde are reproduced in Agency document INFCIRC/203.

that additional quantities of special fissionable material would be available should they be required. A routine procedure for dealing with requests for nuclear material addressed to the Agency has been well established. Full account is taken of the fact that timely supply is of considerable importance for the efficient and economical operation of the installations for which the material is needed.

ANNEX 4

CHECKLIST FOR INFORMATION TO BE INCLUDED IN BIDDING DOCUMENTS[A4.1]

PART 1. DESCRIPTION OF PROJECT

1. Name of project.
2. Owner of the plant.
3. Operator of the plant.
4. Location.
5. Power distribution system and its characteristics.
6. Nominal net generation capacity and permissible variations. Operational mode requirements.
7. Required completion date.
8. Schedule of tendering and letting of contract.
9. Plans for other plants to be built at same site.
10. Number of turbo-generators per unit (if more than one).
11. Planned uses for steam (if other than for turbo-generator).
12. Interconnections (if other than electric) with other nearby thermal plants.
13. Unusual conditions, including special system requirements.

PART 2. SITE CHARACTERISTICS

1. Geography

1.1. Location

a. The exact location and present ownership of the site.
b. Maps of successively larger scale of the site.
c. Height of the site above mean sea level.
d. Boundary of the site and area under the plant owner's control.
e. Why was this particular site chosen.
f. How close to load centres is the site located.
g. Accessibility of the site by rail, road and sea.

1.2. Topography

a. Describe the site and its surroundings in terms of hills, gullies, grading, streams or rivers, shorelines, vegetation, surface soil, surface runoff and other geographical features. To what extent has clearing and rough grading been performed to date.
b. Will retaining walls, breakwaters of landscaping be necessary to prevent soil erosion.

[A4.1] Based on a paper by W.R. Thomas presented at the survey and briefing course on the technical and economic aspects of nuclear power development, held by the IAEA in Bangkok, December 1973.

c. Is the site located in a basin, protected from the prevailing winds by a barrier of high hills or mountains.
d. Is the site subject to flooding.
e. Possible restrictions on chimney height.
f. Photographs of the site.

1.3. Geology

a. Results of test borings at the site.
b. Results of test borings along the line of the most desirable route for cooling water intake conduit of channel every 15 metres starting at the shoreline out to a mean depth of 7 metres. This route is assumed to be perpendicular to the shoreline, but should be checked by soundings to locate the line of maximum depth below the water surface. These borings should penetrate into foundation material, such as shale, sandstone or bedrock, and should extend to at least 6 metres below the bed of the body of water.
c. Soil profiles and load bearing capacity of each type of soil.

2. Population

a. Names of towns and villages within a 20 km radius of the site, distance and direction of each with respect to the site, and current population of permanent residents in each.
b. Population within radii of 1, 2, 3, 4, 5, and 10 miles (or roughly corresponding metric distances) of the site, if possible also divided in 22.5° sectors.
c. Similar information for transient and seasonal inhabitants.
d. Use and ownership of surrounding land areas within a 10 km radius of the site.
e. Plans for future industrial transportation, military or agricultural developments and populated centres within a 20 km radius of the site.
f. Present and future use of the body of water to be used as a source of cooling water within a 10 km radius of the site.
g. Any public sights of ways, paths or beaches touching the site.

3. Natural occurrences

3.1. Meteorology

Meteorological information, recorded at the weather station on or nearest the site, under the following classifications:

3.1.1. Wind

a. Table of wind velocity variation in one year.
b. Percentage of days in a year with the wind from:
north; north-east; east; south-east; south; south-west; west; north-west; and calm.
c. Monthly mean wind speed.

d. Maximum design wind load called for in local building code (kg/m^2).
e. Maximum wind speed recorded in meteorological records.
f. Monthly means of wind speed in the morning, afternoon and night, at altitudes between 3 km and 1.5 km.

3.1.2. Temperature

a. Monthly averages of the daily maximum, daily minimum and daily temperature.
b. Highest and lowest temperatures ever recorded in each month, and the date and the year in which they were recorded.
c. Annual total degree days below 65°F (18.3°C) and above 70°F (21°C).

3.1.3. Cloud and inversion

a. Number of days per year with cloud amount 0,1 to 3, 4 to 6, 7 to 9 and 10 tenths, taking all clouds into consideration.
b. Number of days per year with low cloud amount 0, 1 to 3, 4 to 6, 7 to 9 and 10 tenths.
c. Frequency and duration of temperature inversions at the site.
d. Monthly mean lapse rates (°C per km) at intervals of 0.5 km between ground level and 2.5 km at the site.

3.1.4. Storms and disturbances

a. Mean monthly rainfall (mm).
b. Number of rainy days in each year.
c. Frequency groups of precipitation for each month of the year (mm) in accordance with the standards established by the World Meteorological Organization.
d. Heaviest rainfall in 24 hours in meteorological records and the date and year in which it was recorded.
e. Number of days per year in which the following weather phenomena occurred:

    precipitation 2.5 mm or more
    thunder
    hail, ice or freezing rain (if applicable)
    snow (if applicable)
    dust storms
    squalls
    fog or extreme atmospheric pollution
    hurricanes, typhoons or tornadoes

f. Maximum snowfall and design snow load called for in local building codes.
g. Maximum design load due to the accumulation of rain water on a surface whose position and shape are such to make such an accumulation possible.
h. Will a covered switchyard be necessary.
i. Are there any corrosive elements or dust in the air which would necessitate air filters for ventilation intakes or protective covering for the switchyard or other outdoor equipment.

3.2. Seismology

a. Dates and intensities of recorded earthquakes, landshifting, rockslides, avalanches or seismological disturbances.
b. Number of earthquakes anticipated in the next century.
c. Location and nature of geological faults within a 100 km radius of the site.
d. Location of mines or tunnels within a 5 km radius of the site and the ownership of mineral rights to the site.
e. Horizontal acceleration spectrum and damping factor that buildings must withstand as specified by local building codes.
f. Types of structures and parts of structures which are subject to seismic design regulations.
g. Are existing underwater structures and structures in contact with large water masses in your area designed for seismic shock.
h. Is secondary reinforcement required for structures.

4. Sources of water

4.1. Cooling water

The condenser circulating water may come from one of three sources: an ocean or estuary, a river, or a lake. Consequently, some questions apply to each source of cooling water and others deal with all three sources.

a. Temperature and contents
Mean annual surface water temperature at the site

Monthly mean temperatures, monthly mean maximum temperatures, and monthly mean minimum temperatures over a period of a year at a depth of 10 feet.

Underwater contours to a 30-foot depth at mean water level.

Water temperature at depth increments of five feet at each sounding.

Fluctuations of these water temperatures over a 24-hour period.

Water samples taken about 3 feet from the bed of the body of water along the intake line to determine the amount of solids carried in suspension at high and low water levels.

An assessment of damage to underwater structures by marine growth and local preventative measures used to combat the damage.

Ownership of onshore and offshore water rights.

b. Ocean or estuary

Maximum tide level above mean sea level and minimum tide level below mean sea level.

Maximum height of tide above mean sea level ever recorded.

History of tidal waves or sea spouts.

Description of the ocean bed and marine life, such as fish, mussels, shrimp, barnacles, plankton and algae.

Salinity of the sea water along the intake line.

Direction and velocity of shoreline currents and proximity of sea water intakes or public recreation facilities to the site in the direction of the currents.

c. River

Flow duration curve obtained from data obtained from flow measurements made over the past 20 years.

Maximum flow velocity ever recorded.

Scouring velocity of the river bed and walls.

Type and nature of industries upstream and downstream from the site, at present and planned for the future.

Use of river for hydro-electric power generation, recreational facilities, irrigation, flood control, or navigation at present and in the future.

Limits on effluent temperatures.

Chemical analysis of the river water at the site (see 4.2 Fresh water).

Maximum water level above the mean water level and minimum water level below the mean water level ever recorded.

History of floods.

Description of river bed and marine life, such as fish, crabs, algae, sediment and residue.

d. Lake

Area and mean depth of lake.

Maximum height of waves ever recorded.

Description of lake bed and marine life, such as fish, crabs, algae, sediment and residue.

Direction and velocity of shoreline currents and proximity of lake water intakes or public recreation facilities to the site in the direction of the currents.

Profile of the lake bed to a distance of 1 km from the shore.

Use of the lake for recreational, irrigational, navigational or industrial purposes.

Limits on effluent temperature.

Chemical analysis of the lake water at the site (see 4.2 Fresh water).

Maximum water level above and minimum water level below the mean water level ever recorded.

4.2. Fresh water supply

A fresh water supply of quantities reaching a maximum of about 2000 l/m and averaging about 700 l/m (these quantities are dependent upon the size of the generating station) will be required for operation and during construction. Can fresh water supply be obtained from local lakes, rivers, wells, municipal water supplies or desalination plants? Which of these sources would supply fresh water most economically? What would be the cost of fresh water?

Supply a chemical analysis of a fresh water sample from the source.

Water samples from rivers or streams flowing into the sea should be taken at high tide and low tide. Water samples from other rivers or streams should be taken when the river or stream is in flood and when the river or stream is at its lowest level.

4.3. Hydrology

Contour map of the water table for the area of the site.

Minimum depth of the water level below ground level within the area of the site.

Direction and average velocity of ground water flow.

Location of underground or surface streams.

Permeability of the soil at the depth of the water table and a description of the method that was used to determine this permeability.

Extent of present exploitation and plans for future exploitation of ground water in the area surrounding the site.

Chemical analysis of ground water samples at high tide and low tide if the site is 5 km distant or less from the sea.

Seasonal variations in the level of the water table.

Mean thickness of the layer of saturated soil.

Type and permeability of bedrock at the bottom of the water table.

Depth, location and estimated capacity of water pockets at depths greater than 50 meters.

PART 3. PARTIAL LIST OF GENERAL CONDITIONS

1. Date, place and to whom bids are to be delivered, in how many copies and in what language.
2. Period of validity of offers.
3. Requirements for local supply of materials and services.
4. Methods of payment for local supplies.
5. Safety and other codes applicable to the project.
6. Local regulatory requirements and reference plant requirements.
7. Responsibility for preparing safety reports.
8. Responsibility and procedures for obtaining construction and operating permits and other necessary legal documents.
9. Responsibility for obtaining import licences, paying of import duties and taxes in buyer's country.
10. Packing, labelling and shipping instructions.
11. Buyer's requirements for quality assurance control and inspection.
12. Participation by buyer's personnel in engineering, commissioning and testing.
13. Requirements for training of buyer's operations staff.
14. Mechanism for handling suspension of project, cancellation of contract and delays.
15. Conditions with respect to local accommodation, taxation and living conditions for contractor's personnel located at the site.
16. Security arrangements.
17. Specification of units, definition of terms and abbreviations.
18. Basis for pricing, how escalation is to be charged, changes to the work.
19. Responsibility for obtaining export licences.
20. Delineation of responsibilities for supply of the first fuel core.
21. Position with regard to international safeguards.

INTERNATIONAL
ATOMIC ENERGY AGENCY
VIENNA, 1975

PRICE: US $7.50
Austrian Schillings 124,–
(£3.10; F.Fr. 32; DM 17,–)

SUBJECT GROUP: V
Reactors and Nuclear Power/All