IAEA-TECDOC-1555

Managing the First Nuclear Power Plant Project

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FOREWORD

Energy is essential for national development. Nearly every aspect of development —– from reducing poverty and raising living standards to improving health care, industrial and agricultural productivity — requires reliable access to modern energy resources. States may have different reasons for considering starting a nuclear power project to achieve their national energy needs, such as: lack of available indigenous energy resources, the desire to reduce dependence upon imported energy, the need to increase the diversity of energy resources and/or mitigation of carbon emission increases.

The start of a nuclear power plant project involves several complex and interrelated activities with long duration. Experience shows that the time between the initial policy decision by a State to consider nuclear power up to the start of operation of its first nuclear power plant is about 10 to 15 years and that before specific project management can proceed, several key infrastructure issues have to be in place.

The proper management of the wide scope of activities to be planned and implemented during this period represents a major challenge for the involved governmental, utility, regulatory, supplier and other supportive organizations. The main focus is to ensure that the project is implemented successfully from a commercial point of view while remaining in accordance with the appropriate engineering and quality requirements, safety standards and security guides. This publication is aimed at providing guidance on the practical management of a first nuclear power project in a country. There are many other issues, related to ensuring that the infrastructure in the country has been prepared adequately to ensure that the project will be able to be completed, that are only briefly addressed in this publication.

The construction of the first nuclear power plant is a major undertaking for any country developing a nuclear power programme. Worldwide experience gained in the last 50 years would be of benefit to the countries, utilities and other organizations involved in such endeavors.

The IAEA has collated worldwide experience and developed guidance in all aspects of managing nuclear power plant projects. This guidance was published in a number of technical documents issued during the last two decades. The present publication is aimed to select some relevant elements that provide a general overview of the main activities in managing the first nuclear power project and lists those specific publications where the reader can obtain further detailed information. Target audience is the decision makers, advisers and senior managers in the governmental organizations, utilities, industrial organizations and regulatory bodies in the countries desiring to launch the first nuclear power project

This publication was produced within IAEA program directed to increase the capability of Member States to plan and implement nuclear power programs and to establish and enhance national nuclear infrastructure. The IAEA wishes to acknowledge the assistance provided by the contributors and reviewers listed at the end of the report. The IAEA officers responsible for this work were M. Condu, R.I. Facer and N. Pieroni of the Division of Nuclear Power.

EDITORIAL NOTE

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1. INTRODUCTION

1.1. Background

A number of publications providing guidance on different aspects related with the introduction of nuclear power were developed by the International Atomic Energy Agency (IAEA) since 1980. Although some of these publications were issued over two decades ago, the guidance provided continues to be valid to a large extent for present applications.[1]

The present publication is based on the extensive information contained in the previous publications and aims to provide an introductory overall description of the main project management activities to be undertaken when planning the first nuclear power plant (NPP) in a country. The contents include excerpts from existing publications along with new material to reflect the changes that have taken place over the years and provide references to relevant publications where the user can find more elaborated guidance. Specific activities related to safety, security and development of nuclear infrastructure are dealt with in the IAEA publications within the Nuclear Safety Series and the Nuclear Security Series as well as in forthcoming publications on nuclear energy related subjects.

1.2. Objective

To provide concise practical information on the main project management activities during the stages composing the planning and implementing the first NPP project in a country.

1.3. Scope

The main project management activities in the period starting with the decision to consider nuclear energy as a potential source for producing electricity within the national energy system, up to start of commercial operation of the first NPP are addressed by this publication.

1.4. Users

The target audience for the TECDOC is the decision makers, advisers and senior managers in the governmental organizations, utilities, industrial organizations and regulatory bodies in the countries desiring to launch the first nuclear power plant project.

1.5. Structure

This publication consists of five chapters along with this introduction.

Chapter 2 provides an overview on basic considerations in managing the first NPP for safe, secure and peaceful use.

Chapter 3 describes the five broad stages that constitute the generic planning and implementation schedule of a NPP. It regroups and integrates several long duration activities.

Chapter 4 describes the PRE-PROJECT stage, which is defined as the period starting with the decision to consider nuclear energy as a potential source for producing electricity within the

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[1] IAEA publications can be obtained at: Sales and Promotion Unit, International Atomic Energy Agency, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria. Fax: +43 1 2600 29302; tel.: +43 1 2600 22417; email: sales.publications@iaea.org; http://www.iaea.org/books.

national energy system and ends with the launch of a pre-investment (feasibility) study. This stage can be characterized as conceptual preparatory embracing all technical-economic-regulatory investigations needed for the justifications of such a project.

Chapter 5 describes the PROJECT DECISION-MAKING stage of the NPP project in which many elements particular to a country or to an organization will have to be reviewed carefully to ensure a judicious decision-making and preparatory activities carried out to create national infrastructure to support the launching of the NPP project and to lead to the decision-making to go forward with it.

Chapter 6 describes the PLANT CONSTRUCTION stage of the NPP project planning consisting of project-oriented activities leading to the successful construction, commissioning and acceptance of the first NPP. The PLANT OPERATION and DECOMMISSIONING stages of a NPP project are outside the scope of this publication.

1.6. How to use

This publication can be used as a road map to other more detailed documents and reference material from IAEA for managing the implementation of the first NPP project. The publication is not prescriptive and should be considered as a guide. The quantitative measures given for resource development in this publication should be adjusted by the user to fit the needs and capabilities of the country and the associated organizations. Other IAEA publications with additional information related to the issues covered in this publication are listed in the Appendix III.

2. BASIC CONSIDERATIONS IN MANAGING THE FIRST NUCLEAR POWER PLANT

2.1. National and international legal framework

A wide range of legislation is expected to be in place in a State that has decided to implement nuclear power, the key elements of such legislation being nuclear safety, security, safeguards and liability for nuclear damage. An outline of the legal requirements needed for embarking on a nuclear power programme is presently contained in [1]. The underlying commercial and industrial framework also needs to be considered when developing the corresponding legislation.

International instruments for Member States to consider adopting prior to beginning a nuclear power project include:

- Comprehensive Safeguards Agreement pursuant to INFCIRC/153 (Corr.)
- Additional Protocol pursuant to INFCIRC/540 (Corr.)
- Convention on Early Notification of a Nuclear Accident
- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency
- Convention on Nuclear Safety
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, reproduced in document INFCIRC/546

- Convention on Physical Protection of Nuclear Material, and Amendment
- Vienna Convention on Civil Liability for Nuclear Damage
- Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention, reproduced in document INFCIRC/402
- Protocol to Amend the 1963 Vienna Convention on Civil Liability for Nuclear Damage and Convention on Supplementary Compensation for Nuclear Damage
- Revised Supplementary Agreement Concerning the Provision of Technical Assistance by the IAEA

2.2. Nuclear safety

The fundamental safety objective of protecting people — individually and collectively — and the environment has to be achieved without unduly limiting the operation of facilities or the conduct of activities that give rise to radiation risks. To ensure that facilities are operated and activities are conducted so as to achieve the highest standards of safety that can reasonably be achieved, measures have to be taken:

- To control the radiation exposure of people and the release of radioactive material to the environment;
- To restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation;
- To mitigate the consequences of events if they were to occur.

The fundamental safety objective applies to all nuclear facilities and activities and for all stages over the lifetime of a facility or radiation source, including planning, siting, design, manufacturing, construction, commissioning and operation as well as decommissioning and closure. This includes the associated transport of radioactive material and management of radioactive waste.

Ten safety principles have been formulated on the basis of which safety requirements are developed and safety measures are to be implemented in order to achieve the fundamental safety objective. The principles are described in IAEA Safety Fundamentals No. SF-1, Fundamental Safety Principles, 2006. The safety principles form a set that is applicable in its entirety; although in practice different principles may be more or less important in relation to particular circumstances. The IAEA Safety Standards Series establishes the safety requirements governed by the safety principles as well as recommendations and guidance on how to comply with the safety requirements.

This supposes that an effective nuclear infrastructure has been implemented in due time to ensure that the concerns of all stakeholders (and public especially) are being addressed adequately and that man and machine work together harmoniously to ensure safety.

Also, although prime responsibility for safety rests with the organization responsible for the facilities and activities that give rise to radiation risks, national efforts alone should not be considered sufficient and should be supported by the activities of variety of international organizations that cooperate to ensure an effective global nuclear safety regime.

Key safety elements of an effective nuclear infrastructure include:

- Legal framework

This element includes a legislation establishing an independent and competent regulatory body as well as a regulatory system that provides framework (codes and standards, licensing process, assessments, inspections, enforcement if necessary) within which construction, operation and decommissioning of nuclear facilities can proceed.

- Regulatory competence

The regulator should have the capacity to oversee all stages of the NPP project, including site evaluation, design review, construction, operation, decommissioning and waste management. As well as the operator, the regulator should seek for continuous improvement. He should regularly check for its effectiveness through self-assessments and/or international peer reviews.

- Financial stability

A commitment to nuclear power demands financial capacity not only to acquire a plant but also to fund operations, decommissioning and waste management. This supposes that not only the operator, but the regulatory body, the industry and the education sector dispose of adequate financial resources to maintain adequate conditions for safety over this period of time (i.e. about 100 years from policy decision to site closure after decommissioning).

- Technical competence

After an initial reliance to some extent on skills from abroad, the country should develop through adequate educational and training programmes an indigenous capacity to provide skilled personnel in all areas needed to maintain an effective safety level for the whole duration of the nuclear programme.

- Operator skills and attitude

To ensure its prime responsibility in safety, the operator needs technical competence to operate and maintain its facilities. This requires the availability of staff and management with knowledge and experience, committed to a safety culture where everyone is aware of its individual responsibility for safety. Credit should be taken from experience at all levels including international, to continuously seek for improvements not only in the designs of NPPs, but also in training programmes, organizational structures and plant operation and maintenance procedures.

- Emergency preparedness

Notwithstanding all the efforts to ensure safety, the country should also prepare for the possibility that a nuclear or radiation emergency could arise. Arrangements should be taken with the concerned stakeholders for an effective response at the scene and, as appropriate, at local, regional, national or international levels.

- International connectivity

For obvious reasons, every country should share information with others and learn from their experience. Every country embarking on a nuclear programme should take the opportunity to join the variety of international organizations that constitute the global nuclear safety and operating regimes and benefit of their services as well as of the experience built through these relationships.

2.3. Nuclear power supply market

Ever since NPPs became available for export in the late 1950's, most countries that started using nuclear power, whether industrialized or developing, have adopted the approach of importing the first NPP. It is very likely that this approach would continue to be adopted by any country launching its first NPP in the future.

2.3.1. Supply of nuclear power plants

The implementation of a first NPP project will generally be through importation from an experienced foreign supplier or suppliers. There will be national participation too, which will vary from case to case and will depend mainly on the available infrastructure of the country.

A thorough evaluation of the supply market is needed in order to identify the reactor or reactor types and sizes that are commercially available offering distinct economic or technical attractiveness and to analyse how nuclear fuel cycle requirements can be met. The evaluation will support the selection of the reference concepts for detailed economic and technical analysis and comparison among each other and with alternative projects. The evaluation will also facilitate the final decisions to be taken after the project is firmly committed.

The choice of reactor type for the first NPP should also be seen as a possible long-term commitment to that type for additional NPPs to be built in the future, and also to the type of fuel cycle and associated supply requirements.

2.3.1.1. Provenness and demonstrated licensability

"Provenness and demonstrated licensability" of a NPP lead to the establishment of the national requirements and the criteria in the bidding process for a reference plant which serves for the purpose of the project as a guideline for the following main features:

- design
- performance
- scope of supply
- licensing criteria
- operating experience.

If the application of the provenness criterion were too strict, it could eliminate practically all types of designs of NPPs from the market as no export plant has been a duplicate of an existing one.

Application of the "demonstrated licensability" concept helps to reduce the safety risk involved in the NPP and facilitates the regulatory procedures, even if it does not relieve the buyer's country of its basic responsibilities. It has often been recommended that licensability be demonstrated in the supplier's country through the use of a licensed reference plant, implying an acceptance — by the recipient country — of the supplier's country licensing requirements and procedures. Also cooperation with regulatory bodies of countries of origin of reference plants is advisable.

Where appropriate, various bodies (organizations, companies or individuals) may be designated as competent to work in the nuclear industry, generally or for specific aspects, either by a regulatory, a standards or a purchasing organization. This can be described as recognizing the body as “suitably qualified and experienced” for the purpose for which they are being used in the nuclear project.

This recognition may be given in the form of formal certification, or by a less formal structure of being placed on a register of acceptable bodies or individuals either by regulatory bodies, or by industrial and utility organizations.

2.3.1.2. Nuclear technology developments

New NPPs are being developed today which may not be commercially available for several years. These developing designs achieve safety and economical improvements over existing designs through small to moderate modifications, with a strong emphasis on maintaining proven design features to minimize technological risks.

Substantial design and development programs are underway in several Member States for further technology improvements and for development of advanced NPP designs. This development is proceeding for all reactor lines — water cooled reactors, gas cooled reactors, and liquid metal cooled reactors- so that nuclear power can play an increasing role in global energy supply in the near future.

2.3.2. Supply of nuclear fuel and fuel cycle services

The supply of a NPP and the supply of its fuel must be considered simultaneously. The supply of the NPP fuel must be provided during the whole lifetime of the plant. Failures in supplying the plant with fuel would not only mean being left with an unproductive investment, but would also affect negatively the electricity supply of the country, which might have serious consequences on its economic and industrial activities.

One of the important factors that influence the choice of reactor type is the adoption of the fuel cycle – natural or enriched uranium- and the related services activities. Fuel cycle policy decisions not only affect the first NPP, but also — and possibly even more — the further NPP planning of the country. Though the decision on the first plant does not necessarily mean that all successive plants will have the same type and use the same fuel cycle, there are obvious advantages regarding the built-up of national capabilities if a certain line is followed through.

Other aspects that should be taken into account include:

- Country uranium resources
- Local yellow cake production feasibility or strategy on purchasing and stocking yellow cake
- Enrichment services, if enriched uranium will be used as fuel
- Direct purchasing of finished fuel elements
- Stocking autonomy policies of fuel elements at the plant.

2.3.2.1. Fuel availability

The NPP owner/utility/operator is primarily concerned with two main aspects of the nuclear fuel. The first one is the reliability of the supply of the fresh fuel and the second concern is the handling of the spent fuel. To cater efficiently to these two items, fuel management has been developed as an expertise in itself, vital in both keeping the NPP in operation and holding the costs down.

The nuclear fuel cycle consists of a number of distinct industrial activities which can be separated into two sections: the "front end", comprising those steps prior to fuel irradiation in the NPP and the "back end", which includes the activities concerning the irradiated, spent fuel.

The acquisition by a country of its first NPP typically involves a major degree of dependence on external suppliers, with associated commitments to nonproliferation and international cooperation. The NPP is usually provided initially with fuel for one to four years of operation but it will have to be supplied with fuel over its lifetime of 40, 60 years or more.

The nuclear fuel production and supply has evolved and various international initiatives proposed by supplier countries are currently underway. The status of uranium enrichment is presented in ref. [2].

2.3.2.2. Fuel disposal

After nuclear fuel has been used in a reactor to produce heat for the different purposes, it is known as "spent fuel" and may undergo a further series of steps in the back end of the fuel cycle, which include temporary storage and final disposal, reprocessing and recycling before eventual disposal as waste.

The Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management [3] obliges signatory governments of Member States to take a number of measures to ensure the safety of spent fuel and radioactive waste management facilities and to submit national reports on their activities and policies for peer review every three years.

In the back end of the fuel cycle there are currently three main policy options for management of the spent nuclear fuel:

(1) Storage for 30-50 years and subsequent disposal as high level radioactive waste (HLRW)
(2) Reprocessing to separate plutonium for fabrication of mixed oxide (MOX) fuel to be recycled in light water reactors (LWRs)
(3) Deferral of the decision on whether to reprocess or dispose of the spent fuel.

The first option of storage and final disposal of the spent fuel without reprocessing would be based on the transfer of technologies associated with the on-site storage of spent fuel along with the construction of the NPP. The facilities required should be included as part of the plant. Further treatment of the spent fuel will be a distant requirement and need not be considered as requiring technology transfer in the early stages of a nuclear power development programme. Transfer of spent fuel technology will depend on the country's policy decision with respect to the back end of the fuel cycle.

The second option of spent fuel reprocessing is based on the fact that spent fuel still contains approximately 96% of its original uranium. The uranium in the spent fuel has approximately the natural content of U 235 and there is about 1% plutonium. Reprocessing separates uranium and plutonium from spent fuel by different chemical processes. Recovered uranium can be returned to the conversion plant for conversion to hexafluoride and subsequent nuclear fuel fabrication. The reactor-grade plutonium can be blended with enriched uranium to produce MOX fuel, in a fuel fabrication plant. The economic advantages of reprocessing and recycling compared to storage and disposal are marginal at present but could be more clearly justified if uranium prices increase. Other considerations, such as the use of plutonium by burning it in reactors instead of disposing of it and the more suitable form of the remaining high level radioactive waste (HLRW), could encourage reprocessing. The status of spent fuel reprocessing is presented in [4].

The third option of deferring the back end decision is the cheapest in the short term as it would permit deferral of decisions on HLRW disposal technology and siting.

The role of the government at the back-end has intensified in the past decade, as increasing attention is paid to decommissioning and long-term management of radioactive waste. Government involvement in the back-end of the nuclear fuel cycle can take many forms. The government has the responsibility to define national policy on nuclear waste, defining the process for funding, siting and environmental assessment of the facilities and possibly implement them. In some Member States, governments build and operate the facilities and perform research and development, either generic or site-specific.

Short-term storage and management of radioactive waste, including spent fuel, is the responsibility of the NPP owner/utility/operator, usually as part of the NPP operation license. For the long term storage, central storage or disposal facilities may be required, subject to government regulation.

2.4. Financial market

The availability of adequate and secure financial resources is probably one of the most crucial constrains affecting the implementation of NPP projects. Total financing arrangements for implementing new NPP projects are influenced by overnight costs, construction time and the cost of capital. Although it is expected that new reactor designs will reduce capital costs and construction time of NPPs, total investment costs of nuclear units are likely to remain high as compared to alternatives, in particular to combined cycle gas turbines. Therefore, financing, in the context of competitiveness of total electricity generating costs, is a key issue to be addressed before the successful implementation of a NPP project.

Generally, NPPs are financed by the conventional approach that consists of multi-source financing, where a complete financing package is put together, covering the entire cost of the project. The first source is the investor/owner/operator. Its own resources constitute the basis of the financing package. In addition, bond issues, domestic bank credits and, in case of state-owned or controlled enterprises, funding from the governmental budget may complete the financing needed.

Financing NPPs generally has been facilitated by need for base load electricity, at stable projected production costs, competitiveness of the nuclear option, stable regulatory regime and indirect or direct government support.

The trend to market deregulation and to privatization creates new challenges for financing equipment in the energy sector, in particular large power plants. In the electricity deregulated market the nature of investment risks has changed and investors tend to favor less capital-intensive and more flexible technologies. Other risk factors also play important roles in investment decision, such as regulatory stability, international arrangements, environmental and security of supply polices.

In the case of nuclear power, the financial risks for private investors in deregulated markets may arise from regulatory uncertainties during plant construction and operation, political risks (such as those arising from public opposition), technical risks related to waste disposal and economic risks associated with liabilities for decommissioning and dismantling of NPPs.

The parties in a financing agreement are the financing institution and the buyer of the NPP. The buyer might ask the vendor to provide specific assistance in the process of obtaining and negotiating loans, in the best possible terms and conditions.

2.5. Economics of nuclear power

2.5.1. Nuclear power generation costs

The demonstration that the economics of nuclear power is within the competitive range for inclusion in the generation mix is made based on the specific analyses using a financial model and considering all components of the cost for the lifetime of the NPP. The basic elements entering into calculation of nuclear power generation cost include the following:

- capital/investment cost;
- operation & maintenance (O&M) cost;
- nuclear fuel cycle cost.

In the case of nuclear power, capital/investment costs represent some 60% of the total nuclear generation cost, while O&M and nuclear fuel cycle costs represent some 20% each. These are just rough figures that depend on the size of the reactor, the assumed lifetime and the establishment of a long-term strategy rather than considering one single NPP in the country.

There is also a specific cost associated with national nuclear power programme implementation, known as infrastructure development cost, which include costs for planning studies, development of national infrastructure, transfer of technologies, national participation promotion and domestic nuclear industry development, domestic man power development and nuclear safety regulatory cost.

The economic assessment of nuclear power generation alternative should be performed considering all components of the costs and technical parameters for the lifetime of the NPP. This economic assessment must be performed within specific set of economic ground rules, assumptions (input data) and cost estimates. The most common practice of economic analysis performance is to determine the present values of all costs and benefits of nuclear power and calculate the unit energy cost on a given base data. Unit energy cost calculation should be made for a particular country and site, accounting for all relevant factors and conditions, such as local infrastructure, current international trends in the national and international economy, site characteristics, local participation, technology transfer and human resources. Warehouses and stocking policies for spare parts and consumables, especially when the plant is located in a distant manufacturer's country, should also be taken into account.

The total capital/investment cost, which is the largest component of the plant cost, can be estimated fairly accurately for a given NPP project model. Operation and maintenance costs can be assessed based on the information from the experienced operators of similar NPPs. The fuel cost and the component cost of the nuclear fuel cycle, for short term and long-term contracts can be obtained from international fuel suppliers. Conservative assumptions should be taken into account for estimating nuclear spent fuel and decommissioning costs of the plant. The infrastructure developments costs, which include the national grid extension, are more complex to assess and should be spread over a number of NPPs and other technological developments in order not to adversely affect the economics of the project.

Other necessary input data for the unit energy cost calculation are in connection with the specific mode of project financing:

- Total amount for funding;
- Debt to equity ratio;
- Interest rates for the internal and external loans;
- Escalation/inflation rates (foreign and local).

The total amount for funding includes the total capital cost and financial cost for funding including interest during construction (IDC). The interest rate on the loans needed to meet the project cash flow requirements during the construction period has an impact upon the IDC. Also the escalation/inflation rates during plant construction will impact on the total capital/investment costs.

The discount rate for the economic assessment of nuclear power generation, specific also for the free electricity market, is dependent on the particular model of project financing and on the potential investor's expectation (profit) from the project. The discount rate will be defined by the potential investors or by the utility/operator or by the government for the energy sector, depending of the financing model of the NPP project.

The NPP lifetime plays an important role for the determination of the annual fixed charges due to the depreciation of and interest on the capital investment. Also the NPP lifetime and the discount rate will define capital recovery factor to be used for calculating the annual fixed charges on capital investment.

The financial analysis should be performed using financial models and through different financial tests, the results being the following significant financial indicators, which demonstrate the economic viability of the NPP project:

- Unit energy price [US $/MWh or Euro/MWh];
- Cumulative Cash Flow;
- Equity requirements;
- Annual Debt Service Cover Ratio;
- Loan Life Cover Ratio.

The assessment of the NPP project should include a sensitivity analysis assigning reasonable ranges of variations to the most relevant parameters and data. The sensitivity analysis should examine potential financial bottlenecks and risks associated with the project construction.

A summary of the available IAEA analysis models regarding electricity and energy system development, energy investment planning and energy environment policy formulations, include the following:

- **MAED:** Model for Analysis of Energy Demand
- **WASP:** Wien Automatic System Planning Package
- **ENPEP:** Energy and Power Evaluation Program

- **FINPLAN:** Model for Financial Analysis of Electric Sector Expansion Plans
- **MESSAGE:** Model of Energy Supply Systems and their General Environmental Impacts
- **SIMPACTS:** Simplified Approach for Estimating Impacts of Electricity Generation

Further information can be obtained in:
http://www.iaea.org/OurWork/ST/NE/Pess/index.shtml

2.5.2. Liabilities

Nuclear power liability

Competition will put pressure on the utility/owner/operator to clearly identify and quantify future economic liabilities of NPPs and to include them in electricity prices. The current liabilities of NPP and associated insurance schemes, whose costs are rather well established, are not likely to change in a deregulated market.

Decommissioning and radioactive waste management liabilities may be the most important of the various economic risks of nuclear power in competitive electricity markets. The associated concerns include accuracy of the estimated future cost, adequacy and availability of funding provision to meet those costs and stability of the regulatory requirements that impact on the costs.

Civil liability

It is recognized that the consequences of an accident occurring at a nuclear installation or during the transport of nuclear substances would not stop at political or geographical borders, that victims should be compensated equitably and that such compensation could only be assured through the establishment of an international nuclear liability regime. The regime is based on the treaties, conventions and protocols mentioned in 2.1 and listed in Appendix I.

2.6. Safeguards

Safeguards are activities by which the IAEA can verify that a State is living up to its international commitments not to use nuclear programmes for nuclear-weapons purposes. Safeguards are based on assessments of the correctness and completeness of a State's declared nuclear material and nuclear-related activities. Verification measures include on-site inspections, visits, and ongoing monitoring and evaluation. Basically, two sets of measures are carried out in accordance with the type of safeguards agreements in force with a State, i.e.

- Comprehensive safeguard agreements- INFCIR 153 (Corrected);
- Additional Protocol- INFCIR 540 (Corrected).

The additional measures within this additional protocol enable the IAEA to expand its rights of access to information and sites and to use the most advanced verification technologies.

2.6.1. Objective of safeguards

In comprehensive safeguards agreements the objective of safeguards is defined as the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or other nuclear devices or for purposes unknown and deterrence of such diversion by means of early detection.

2.6.2. Essential elements of safeguards

The essential elements of safeguards are organized to provide an information system that permits the IAEA to monitor operational activities so that the validity of the operator's account of fuel operations can be verified [5].

The IAEA's safeguards activities monitor the physical activity in the storage and material transfer areas for accountancy verification purposes. Any activity observed that does not correspond to that declared will initiate a pre planned process to re-establish confidence that the declared record reflects the real inventory. That process might lead to an examination and validation of the entire inventory, an expensive task for the operator, which should be avoided.

Safeguards agreements are negotiated on the governmental level, while the utility/owner in charge of the NPP project becomes involved in the implementation of the agreements. Thus, the utility's main tasks consist of performing detailed nuclear materials accountancy, reporting and providing counterparts at the plant to the safeguards inspectors.

2.7. Security of nuclear materials and other radioactive materials

Nuclear security activities contribute to the prevention and detection of, and response to, malicious act and nuclear terrorism. The international instrument for that is the Convention on the Physical Protection of Nuclear Material signed on 3 March 1980.

INFCIRC/225/Rev. 4 is the principal source for the international guidelines relevant to the physical protection of nuclear material and nuclear installations. As part of building nuclear security framework, work is ongoing at the IAEA on the development of additional guidelines and recommendations. These include guidelines on the export-import of radioactive sources based on the provisions of the revised Code of Conduct on the Safety and Security of Sources; on the development and maintenance of a data basis; on the functional specifications for detection instruments; on identifying 'vital areas' in nuclear facilities; on the development of security culture; on the security of transport of radioactive sources; and on combating cyber attacks on nuclear installations. The IAEA has initiated a Nuclear Security Series of Documents to provide a coherent and integral framework for documents related to nuclear security. More information can be obtained in: http://www-ns.iaea.org/security/default.htm

2.7.1. Physical protection

The purpose of physical protection is to protect nuclear facilities and to minimize the possibilities of sabotage or unauthorized removal of nuclear material. The responsibility for the establishment, implementation and maintenance of a physical protection within a State rests entirely with that State. To meet this commitment, a State considering the introduction of nuclear power and the use of special fissionable material must set up a system for adequate physical protection of nuclear material and facilities. The State must promulgate and review regularly its comprehensive regulations for the physical protection of nuclear material and facilities, whether in State or private possession. The main elements of such a system would include the following:

- Determination of responsibility, authority and sanctions and overall coordination between the various authorities and organizations involved;
- Regulatory requirements for compliance with physical protection conditions;
- Categorization of nuclear material based on potential hazards depending on type of material, isotopic composition, physical and chemical form, radiation level and quantity; and
- Information system which enables the State to be informed of every change at nuclear sites or regarding transport of nuclear material that may affect implementation of physical protection measures.

In July 2005 a conference was convened to amend the Convention and strengthen its provisions. The amended Convention makes it legally binding for States Parties to protect nuclear facilities and material in peaceful domestic use, storage as well as transport. It also provides for expanded cooperation between and among States regarding rapid measures to locate and recover stolen or smuggled nuclear material, mitigate any radiological consequences of sabotage, and prevent and combat related offences. The amendments will take effect once they have been ratified by two-thirds of the States Parties of the Convention.

2.7.2. Radioactive material

Concerning radioactive sources, the General Conference of the IAEA approved a Code of conduct on the safety and security of radioactive sources [6]. This Code applies to all radioactive sources that may pose a significant risk to individuals, society and the environment, that are the sources referred in Annex 1 of the Code. States should devote appropriate attention to the regulation of other potentially harmful radioactive sources. This Code does not apply to radioactive sources within military or defense programmes. The objectives of this Code are, through the development, harmonization and implementation of national policies, laws and regulations, and through the fostering of international cooperation, to:

- Achieve and maintain a high level of safety and security of radioactive sources;
- Prevent unauthorized access or damage to, and loss, theft or unauthorized transfer of, radioactive sources, so as to reduce the likelihood of accidental harmful exposure to such sources or the malicious use of such sources to cause harm to individuals, society or the environment; and
- Mitigate or minimize the radiological consequences of any accident or malicious act involving a radioactive source.

2.8. Management system

A major undertaking such as a NPP project requires the implementation of an integrated management system directed to provide a single framework for the arrangements and processes to address all the goals of the organization. The goals include safety, health, environmental, security, quality and economic plus other considerations such as social responsibility.

Personnel, equipment and organizational culture as well as the documented policies and processes are constituent parts of the management system. Requirements for integrated management systems are established in, for example, IAEA Safety Standards [7] and other international standards.

2.8.1. Integrated approach

Reference [7] suggests replacing the old quality assurance/quality management (QA/QM) thinking with the integrated management system approach. The main aims of an integrated management system are:

- Bringing together in a coherent manner all the requirements for managing the organization;
- Describing the planned and systematic actions necessary to provide adequate confidence that all these requirements are satisfied; and
- Ensuring that health, environmental, security, quality and economic requirements are not considered separately from safety requirements, to avoid the possibility of their potential negative impact on safety.

Safety is paramount within the management system, overriding all other demands. The management system identifies and integrates the requirements contained within the applicable codes, standards, statutory and regulatory requirements of the Member State as well as any requirements formally agreed with stakeholders.

2.8.2. Management system and safety culture

The management system promotes and supports a strong safety culture by:

- Assuring a common understanding of the key aspects of the safety culture within the organization;
- Providing the means by which the organization supports individuals and teams to carry out their tasks safely and successfully, taking into account the interaction between individuals, technology and the organization;
- Reinforcing a learning and questioning attitude at all levels of the organization; and
- Providing the means by which the organization continually seeks to develop and improve its safety culture.

2.9. Regional and interregional cooperation

Probably all plans to introduce a major modern technology involve cooperation between nations.

Cooperation between nations has taken several forms:

- Bilateral or regional cooperation;
- International cooperation chiefly through the IAEA.

The IAEA continues to provide most of the support that its members require, based on substantial experience in serving as bridge for technical cooperation between nations.

Other forms of cooperation takes place between regulatory bodies, private sectors (between firms and within multinationals and WANO), and among universities, research institutes, and non-governmental organizations.

2.10. IAEA assistance

The IAEA has considerable experience in assisting Member States who are considering or have already decided to introduce nuclear power. For example, support can be provided for implementing the construction and operational stage of a NPP to the extent that the State has demonstrated that it has established the essential elements of a national framework. Advice and guidance on obligations and commitments can be provided during all stages of a nuclear programme.

While the IAEA can assist, within available resources, with training on all aspects relating to the introduction of nuclear power, the State's own commitment to develop the necessary human resources, skills and core competencies and understanding of the requirements associated with nuclear power programmes is essential. It is also desirable that a State and owner/operating organizations obtain advice from appropriate international organizations and commercial suppliers.

With the exception of issues relating to commercial decisions, the IAEA can also assist by providing technical support for the owner operator for the assessment of potential technology, the managerial approaches that can be used in the implementation of a project, and issues related to ensuring the safe and economic operation of a NPP.

3. NUCLEAR POWER PLANT PLANNING AND IMPLEMENTATION STAGES

3.1. Project stages

The NPP project planning and implementation is made up of several long duration activities which can be characterized as:

(1) Conceptual and preparatory activities that embrace all investigations on technical-economic, safety and regulatory aspects needed for the justifications of a NPP project;
(2) Preparatory activities to create the national infrastructure necessary to support the launching of the NPP project and the decision to go forward with the project;
(3) Project oriented activities leading to the successful design, construction, commissioning, start-up, warranty tests and acceptance of the first NPP and potentially to subsequent ones;
(4) Performance oriented activities leading to the safe and reliable operation and life management of the NPP and;
(5) Post operation activities leading to decommissioning of the NPP.

Combined together, they constitute the generic implementation stages of a NPP project planning which is shown in Figure 1. All these activities are normally performed by several different private and public (government controlled) organizations, each being responsible for a limited group of activities with a common goal, i.e. the achievement of the NPP programme objectives.

These activities can be regrouped in five distinct stages which makes the NPP project. These stages are:

- Stage 1: Pre-Project;
- Stage 2: Project Decision-Making;
- Stage 3: Plant Construction;
- Stage 4: Plant Operation;
- Stage 5: Plant Decommissionning.

Section 3.2 defines and describes the different stages of a NPP project as is commonly recognized by the industry. As demonstrated in real time, activities corresponding to different stages can and very often are done in parallel.

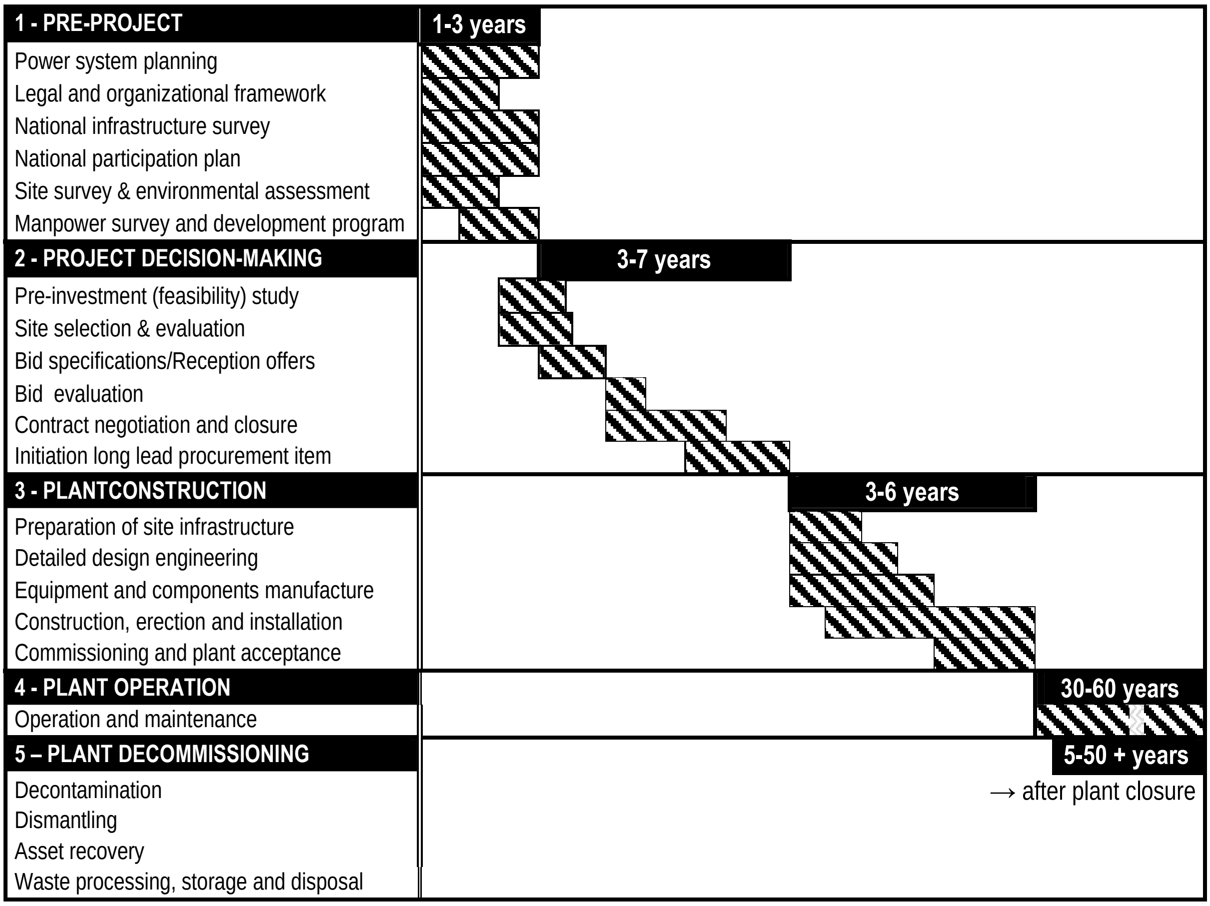

Fig. 1 Generic implementation stages of a nuclear power plant project.

3.2. Stages description

3.2.1. Stage 1: Pre-project

Is defined as the period starting with the decision to consider nuclear energy as a potential source for producing electricity within the national energy system and ends with the launch of a pre-investment (feasibility) study for the first NPP project.

This initial stage can be described as relating to conceptual preparatory activities embracing all technical-economic-regulatory investigations needed for the justifications of a NPP project.

It is to be recognized that the introduction of nuclear power and nuclear technology in a country creates specific new requirements on the country’s infrastructure and requires a national commitment on a long-term basis involving substantial efforts.

The activities performed during the Pre-project stage are mainly related to:

— National energy supply planning;
— Electric power system planning;

- Cost estimation;
- Nuclear power programme planning;
- International conventions and agreements;
- National infrastructure survey;
- National participation plan;
  - Long term nuclear power programme policy and commitment
  - Organizational structure
  - Management systems
  - Industry
  - Science and technology
  - Human resources development
  - Legal framework
  - Financing;
- Sites survey;
- Reactor technology survey;
- Environmental assessment;
- Public acceptance;
- Selection of a consultant or consultants.

The overall manpower needs for that stage is relatively modest, mostly oriented at directing, coordinating and registering data, but do involve a large number of organizations (private and public-government controlled). For that purpose, senior governmental directions are required to insure full participation and cooperation of all entities invested in that stage.

3.2.2. Stage 2: Project decision-making

This stage is defined as the period starting with the initiation of a pre-investment study which looks at the introduction of nuclear energy as a reliable and economical source of energy to meet the demand of the national energy system and ends with the closure of a contract for the purchase of a NPP.

This stage can be described as preparatory activities to create a national infrastructure to support the launching of the project [8] and lead to the decision-making to go forward with it.

For the successful introduction of nuclear power in any country, an essential element is a clear understanding at the decision-making level of the specific aspects of nuclear power, and a thorough knowledge of the tasks and activities to be performed as well as requirements, responsibilities, commitments, problems and constraints involved.

The activities performed during the project decision-making stage are mainly related to:

- Completion of a pre-investment study;
- Site evaluation and qualification;
- Evaluation of the nuclear power supply market;
- Establishment of a management system;
- Completion of implementation of the conformity plan related to legal framework;
- Implementation of all international conventions and agreements;
- Regulatory requirements;

— Selection of a contractual approach;
— Preparation of bid invitation specifications (if competitive bidding process is used);
— Bid evaluation;
— Financing plan;
— Negotiation and closure of a contract or contracts;
— Technology transfer and training requirements;
— Public acceptance;
— Owner's management organization.

The overall manpower needs for that stage are relatively few (50 to 100) but highly qualified professionals. The relevant staff should preferably have professional experience in the coordination and performance of complex interdisciplinary studies. The needs start to increase strongly when the commitments are made (letter of intent, contract, etc.) to build the plant. The involvement of a knowledgeable consultant is recommended.

3.2.3. Stage 3: Plant construction

This stage is defined as the period immediately following the closure of a contract for the purchase of a NPP and ends with the completion of the commissioning stage of the plant and its acceptance which allows the utility starting commercial operation.

This stage can be described as project-oriented activities leading to the successful construction, commissioning and acceptance of the first NPP.

The activities performed during the plant construction stage are mainly related to:

— Project management;
— Plant safety
    - Safety concepts and implementation of safety objectives
    - Safety analysis report and licensing application;
— Project engineering
    - Plant conceptual design
    - Basic and detailed design engineering
    - Preparation and review of equipment and plant specifications;
— Procurement and expediting of equipment and materials;
— Manufacturing of equipment and components;
— Management systems;
— Plant construction, erection and installation
    - Site preparation and infrastructure
    - Erection of plant buildings and structures
    - Plant equipment, components and systems installation;
— Plant commissioning and acceptance;
— Turnover to operation;
— Safeguards and physical protection;
— Security;
— Public information.

The overall manpower needs for this stage are higher than for any other stage. Within this stage, manufacturing and construction are the activities that have by far the largest manpower requirements, of the order of 6000 people during its peak period. Most of these (about 85%) will be technicians and craftsmen. The present tendency to increase significantly the prefabrication and the modularization of sizable part of a nuclear plant will greatly modify the requirements for site manpower. In the nuclear power industry, the requirements for unskilled labour are very low (of the order of 10%) although in some countries their proportion may be considerably higher, mainly owing to local labour practices and employment policies. Professionals during design and construction periods are needed primarily for project management and engineering (250 to 350). In addition, manpower is required to perform the supporting activities: NPP project planning and coordination, regulatory and licensing activities, fuel cycle activities, research and development, education and training.

3.2.4. Stage 4: Plant operation

Is defined as the period at which the plant starts commercial operation and ends at the time when the decision to decommission the plant is made.

This stage can be described as performance oriented activities leading to the safe and reliable operation and life management of the plant.

The primary concern of any NPP operator resides in the safe and reliable operation of its unit. Taking into account the actual expectation of the plant life (40 to 60 or more years), this represents the most extensive endeavour in the NPP project.

The activities performed during the plant operation and life management stage are mainly related to:

- Operation management;
- Outage management;
- Technical support;
- Maintenance management;
- Configuration management;
- Procurement management;
- Plant life management;
- Fuel cycle management;
- Waste management;
- Management systems;
- Training and re-training;
- Emmergency plan rehersals;
- Radiological protection and environmental surveillance;
- Safeguards;
- Physical protection;
- Licensing and regulatory surveillance;
- Public information and public relations.

The overall manpower requirements for that stage are not so much directed by the plant output capacity but mainly by the policies regarding the uses of external contractors for such activities as preventive maintenance and planned shutdown. For guidance, the manpower requirements can be defined as an average of one worker for one megawatt electrical of gross capacity of the plant (680 MWe gross capacity would require approximately 680 workers). This average can vary significantly with the experience of the operating utility and also when more than one plant is located on the same site. This average value of workers per MWe is not linear and tends to be as low as 0.7 as the plant gross capacity increases especially for multi-units station. Other major factors affecting this value reside in the local labour practices and sub-contracting capabilities.

3.2.5. Stage 5: Plant decommissioning

This stage is defined as the period starting with the decision to decommission the plant is made and ends with the return of the area, used originally by the plant, to its original conditions or to a state allowing this area to meet the intent of its future use.

This stage can be described as post operation activities leading to decommissioning of the plant and management of the waste within the frame of the country's long term waste management programme.

At the end of its operating life, a NPP has to be decommissioned. A useful life of 30, 40 and now of 60 years with the new designs being proposed should be taken into account. The plant life could be extended beyond these durations with suitable life management programmes that include control of degradation processes, maintenance, repair and refurbishing and replacement of plant components.

There are three recognized decommissioning strategies:

- **Immediate dismantling** is the strategy in which the equipment, structures and parts of a nuclear facility containing radioactive contaminants are removed or decontaminated to a level that permits the facility to be released for unrestricted use, or with restrictions imposed by the regulatory body. In this case decommissioning implementation activities begin shortly after permanent cessation of operations. It implies prompt and complete decommissioning and involves the removal and processing of all radioactive material from the facility to another new or existing licensed nuclear facility for either long-term storage or disposal.
- **Deferred dismantling (sometimes called safe storage, safe store or safe enclosure)** is the strategy in which parts of a nuclear facility containing radioactive contaminants are either processed or placed in such a condition that they can be safely stored and maintained until they can subsequently be decontaminated and/or dismantled to levels that permit the facility to be released for other uses.
- **Entombment** is the strategy in which radioactive contaminants are encased in a structurally long-lived material until radioactivity decays to a level permitting unrestricted release of the nuclear facility, or release with restrictions imposed by the regulatory body. Because radioactive material will remain on the site, this essentially means that the facility will eventually become designated as a near surface waste disposal facility as long as it can meet the requirements for a near surface disposal facility.

Deferred dismantling and entombment strategies also allow for the processing and removal of some radioactive material from the facility, even though these activities may be delayed or only partially implemented.

The costs of decommissioning NPPs including disposal of associated wastes usually do not exceed 2% of the total costs of electricity generation. Some countries include fees in their pricing structure to cover the estimated cost of decommissioning.

The overall manpower requirements for the decommissioning stage are directly related to the strategy selected. Either one will require highly qualified staff with similar qualifications as the one used in the implementation stage with particular ones highly knowledgeable in working under high radioactive environment. Depending on the strategy selected the manpower requirements can range from a few hundreds to more than 1000 people.

3.3. Generic implementation stages of a nuclear power plant project

The generic implementation stages of a NPP project were shown in Figure 1 as an example. The schedule for performing each of the activities stated in the five stages described above depends of many factors, and is affected largely by the amount of planning and the adequacy, level of expertise and sufficiency of the staffing of the project management organization. It also depends on the approach adopted for dealing with the various tasks. There is no precise rule that would define the time period required for each stage and it may vary over a wide range from case to case depending on the prevailing situation and conditions.

Approximate estimates, however, may be obtained from previous experience, which would serve to provide guidelines and might give an indication of the ways and means that could lead to shortening or at least not unduly prolonging the overall time schedule of a given project in a particular situation. The following conditions can greatly modify the overall duration of a NPP project, and in fact are the ones on which the industry as a whole is working on at all levels:

- Licensing process or regulatory and environmental issues have been resolved by the time design is complete;
- Design is complete before first concrete is placed;
- Nuclear qualified equipment/materials are available at the appropriate time in correct and sufficient quantity;
- Sufficient qualified manpower is available;
- Modularization is used to the extent possible.

In order to forecast the overall schedule to deploy a NPP project, the interaction of the different components of the licensing process must be coupled with the project activities and as such, with the site preparation, construction, commissioning, operation staff training and start-up activities.

The periods shown for different activities in Figure 1 as well as the starting points are approximate and should be considered only indicatives. Supporting activities of the NPP project are not included; they begin even before the pre-project activities are started and continue throughout the project. Additional major factors affecting the project schedule are:

- The time needed to make decisions;
- The time to establish the national nuclear law;
- Licensing requirements and procedures changes;
- International conventions and agreements;
- Financing arrangements;

- Project management efficiency;
- Management systems implementation;
- Unforeseen manufacturing or construction problems;
- Late alterations of the design;
- First of a kind issues;
- Strikes;
- Clima / Weather conditions;
- Interferences during installation;
- Delays in procurement of components;
- Non-conformances & corrective actions backlog;
- Public acceptance.

4. PRE-PROJECT STAGE

This is the period starting with the decision to consider nuclear energy as a potential source for producing electricity within the national energy system and ends with the launch of a pre-investment (feasibility) study for the first NPP.

4.1. Organizational structure

The initiation and formulation of a NPP project as well as subsequent implementation need efficient organizational structures for the management of required activities at the government as well as utility, industries, research and development (R&D), and educational institutions involved.

The first task to be performed, when the introduction of a NPP in a country is considered, is the setting up of a national organization to be in charge of the planning and coordination of the NPP project, including all related activities.

In most countries that have started a NPP project such an organization has been initially formed by Atomic Energy Commissions, or by Governmental Ministries or Authorities concerned with the energy resources and development, such as the Ministries of Energy or Industry. In some cases, the organization was set up through the establishment of a separate body, the "Nuclear Power Implementation Agency" [8], in which the appropriate divisions or departments of the ministries and organizations concerned were represented.

Whichever type of organization is formed, it is essential that this organization be totally devoted and solely directed to the NPP project objectives and the related activities, during the various stages of its planning and implementation. This planning and co-ordinating organization would be the leading organization and assume the overall responsibility for the planning and initiation of the various tasks to be performed, and for the direction and coordination of the work to be carried out by the different parties involved in the NPP development.

The NPP project activities are usually performed by several national organizations together with national and foreign consulting and architect engineering firms, suppliers and contracting companies, as well as the utility/owner. The distribution of tasks, functions and responsibilities between the organizations involved follows similar patterns to those for any other conventional power or industrial plant, but in addition, there will be a specific nuclear regulatory organization, the "nuclear regulatory body". The functions of this organization includes establishment of safety requirements and regulations, independent safety assessments and reviews of safety analysis reports, authorizations, inspections, enforcement, coordination with other national and international organizations, and public information.

There is no universally applicable organizational framework that is equally applicable to every country and in each situation. It should also be recognized that the formation of the organizational structures is a continuous and gradual process. As the NPP project develops appropriate changes are gradually introduced according to the needs and available resources.

4.2. Project management system

The overall responsibility for ensuring the fulfillment of the NPP project requirements is placed on the owner. To meet the whole requirements, it is necessary, during the pre-project stage, to establish, implement, assess and continue improve the management system (see 2.8) which integrates all the requirements of safety, health, the environment, security, quality and economics and ensures that safety is properly taken into account in all the activities related with the NPP project. Guidance in this area can be found in IAEA's Safety Standards [7] and [9].

4.3. National energy supply planning

Planning for and assessing energy sector development is becoming increasingly complex with the recognition that social, economic and environmental aspects of energy are intrinsically linked. Each energy option or technology, besides direct costs, has varying degrees of social and environmental costs and benefits. Energy planners and decision makers are confronted with the need to strike a balance among all these while choosing any option or technology. The complexity of the task is compounded by energy market restructuring which has become necessary almost everywhere as high demand for energy investment funds squeezes public sector budgets.

Each country is responsible for the organization and management of its energy supply planning of which electricity supply is generally an important source. National energy supply planning is a continuous and rigorous activity due to the necessity of meeting energy demand through an ever-changing environment. Constant updating and adjustments are necessary whether nuclear power is considered or not. The implementation of additional sources of supply requires long and costly processes involving large investments.

Electricity supply expansion planning might fall under the direct responsibility of a governmental authority or it might be performed by electric utilities supervised, controlled or regulated by the government. Electricity supply is more and more market driven with the ever increasing privatization and deregulation scheme within the globalization world.

National energy supply planning process consists mainly of the following:

— **National energy market analysis:** should include surveys of past trends, current energy balance, energy demand by sectors, energy resources available, demand forecast, supply alternatives and share of electric energy in the overall energy market. In addition, such analysis has to take into account the national objectives or policies regarding national independence of energy supply. The results will lead to the elaboration and definition of energy supply options and to the development of policies and strategies for the energy sector in the country concerned.

- **Structure of the national energy market:** should show a plan to implement an energy balance at the national level. Main components are:
  - Final energy consumption by energy forms and sectors;
  - Primary energy production by energy sources and forms;
  - Domestic energy production, imports and exports;
  - Cost structure of energy produced and consumed.
- **Survey of energy resources:** To develop a national energy policy, a survey of the country's energy resources available as well as potential ones is needed. The most relevant energy resources to be surveyed are uranium, hydro-power, coal, lignite, oil and natural gas. A survey of other energy resources, in particular the renewable ones, such as geothermal, wind, biomass, tidal, solar, etc., should also be performed since one or more of these might become relevant within the period considered The energy resources survey should not be carried out in isolation from the other activities associated with the NPP project planning. Indeed, systematic feed-in and feedback of information in relation to the evaluation of power market /system review, potential alternatives for power generation plant, economic review, etc, are major factors in the planning work.
- **Energy demand forecast:** Constitutes the frame of reference for any analysis regarding the composition of the energy supply development [10]. For the purpose of providing a basis for NPP planning studies, long-term energy demand forecasts are required. The validity of the forecasts lies in general not so much in whatever methodology is adopted, but in the profound knowledge of energy systems and uses, and of the macro-economic development of the country concerned. In order to provide assistance to the Member States, the IAEA has developed a special model known as the Model for Analysis of Energy Demand (MAED) [11]. The main purpose of the MAED is to provide a flexible framework for exploring the influence of social, economic, technological and policy changes on the long-term evolution of the energy demand.
- **Energy supply planning**: To determine long term energy supply and demand balance for a given country. It should be based on the final and primary energy demand forecast of the country and should take into account the major constraints that could limit the development of energy supply, taking into consideration alternative energy supply strategies. Relatively simple to very sophisticated methodologies have been developed and are available worldwide for such analysis. The results will lead to the elaboration and definition of energy supply options and to the development of policies and strategies for the energy sector in the country concerned.

4.4. Electric power system planning

The growth of energy demand comes from different sources. Electricity usually plays an important role in ensuring the total energy demand is met. For that purpose, an electricity market analysis is required from which the electric power system expansion planning will be derived.

- **Electricity Market Analysis** to provide the basis for the planning of the electric power system expansion. It consists of:

- Demand structure and forecast: a detailed and comprehensive survey of the consumer market and analysis of its past development is required to establish the starting point for electricity demand forecasts.
- Power system survey: to establish the basic characteristics and parameters of the existing system together with any committed expansions (under construction, ordered or decided).

— **Electric Power System Expansion Planning**: prime objectives of electric utilities are reliable supply of electric energy at the lowest possible cost and maximisation of profit, with attention to ensuring public safety and environmental protection. The traditional method of evaluating the competitiveness of NPPs with other types of generation plants has been to calculate assumed plant load, generating costs for each type of plant using suitable capital, operating and fuel cost estimates along with plant life expectation and cost of money. Financial implications of an expansion plan for a power generating system needs also to be addressed.

— **Power Technology Forecast**: evolution of arquitectures, supply systems, demand systems, power efficiency in major components, in addition to material, etc. This can anticipate inflexions in electricity demand trends.

— **Power Arquitecture Forecast**: evolution of min/max power ratios to capacity, which tend to determine base and peak load. This depends mostly on the industrial maturity within the system.

4.5. Nuclear power plant project planning

NPP project planning consists of a long-term development strategy that includes a series of activities related with the study, acquisition, design, construction, commissioning and operation of the NPP. It also includes the fuel cycle activities required for the provision of fresh fuel and the disposal of spent fuel and waste, together with the development of the necessary regulatory and supporting infrastructures and services. Thus, NPP project planning becomes a major undertaking involving a great variety of activities, several organizations, both public and private, large human and material resources and a substantial effort at the national and international level. Appendix II provides an example of elements to be considered while performing NPP project planning.

When consideration is given to the introduction of nuclear power as a mean of supplying electricity (heat production and desalination could also be considered as secondary objectives), the first task is to perform a nuclear power plant planning study (NPPPS).

4.5.1. Objectives of a nuclear power plant planning study

The primary objectives of a NPPPS study are:

— The establishment of the need for and viability of the NPP as an alternative to other electricity generation sources;

— The determination of the extent and schedule of the NPP project development that might be required.

The results of the NPPPS will define the demand for nuclear power and constitute the basis for planning the NPP aimed at satisfying this demand.

4.5.2. *Process for nuclear power plant planning study*

In a NPPPS, the long-term (20 to 30 years) energy needs and the extent of meeting those needs by the available resources should be examined. A comparison of the available energy options and the merits of various expansion plans for the development of the electricity supply system should be carried out. This comparison would provide the basic elements upon which the role that nuclear power could play in the long-term energy programme should be assessed. This evaluation should include, in addition to the economic competitiveness of nuclear power with alternative energy options, a number of other factors and considerations, such as:

- Financial requirements and viability;
- Assurance of the energy supply;
- Influence on the country's overall economic, technical, social, and industrial development;
- Effects on the society and the environment;
- Disposal of radioactive waste;
- National infrastructure requirements and capability;
- Manpower requirements and development;
- Sources and assurance of supply for the NPP, nuclear fuels and fuel cycle services.

Important factors to be taken into account when defining the size and timing of the NPP to be installed are:

- Compatibility with the electric system (size and stability);
- Lead times necessary for plant construction and for infrastructure development;
- Commercial availability of a NPP of a given size;
- Cost estimates, foreign currency and financial requirements.

A NPPPS is programme-oriented and therefore its scope will be long-term. A wide coverage of all relevant factors is more important than a detailed in-depth study of some particular aspects. Of course, this does not mean that detailed in-depth studies should be avoided. On the contrary, these would tend to increase the level of confidence and credibility of the results and thus facilitate the decision-making process. The NPPPS will lead to the determination of policies and strategies. Within the framework of the NPPPS, detailed siting and pre-investment studies will be required for the NPP.

The detailed actions to be taken in the early stages of NPP project planning are summarised in Table 1. It represents the "integrated package" of activities that have to be performed. It shows a very large number of separate activities; each will comprise several more detailed activities.

They will have to be carried out in a large number of organizations and integrating these activities into a coherent programme with orderly progress will be a major undertaking. The tools available are the classical ones in the management of any major programme or project, i.e. good communication, coordination, follow-up, scheduling, risk analysis and decision-making. It would, of course, be an advantage if all activities could be performed from a central unit, but this often cannot be achieved in reality. A number of authorities, institutions and organizations, each with its own established mandate, are likely to be involved and lack of coordination and cooperation among them could delay or even block nuclear power programming.

TABLE 1 INTEGRATED PACKAGE OF ACTIVITIES IN NUCLEAR POWER PLANT PLANNING (REF. [12])

STAGES	ACTIONS	OBJECTIVE
A. CREATING THE BASIC PLANNING COMPETENCE	- Define the organizations and responsibilities for energy and electricity system analysis in planning for expansion. - Decide on the role environmental and health issues should have in the analysis of energy expansion plan based on options. - Establish and train a qualified energy and electricity-planning group, equipped with state-of- the-art models and methodologies. - Identify sources for data and information required for planning studies. - Set up a group with defined responsibilities for public information on general energy issues, including relationships with economic development, energy supply security and environmental protection agencies. - Develop an energy and electricity supply plan, taking into account all possible options and the consequences of excluding one or more of them.	***TO INCLUDE NUCLEAR POWER OPTION IN PLANNING***
B. EXAMINING THE NUCLEAR POWER OPTION	- Survey possible sources for assistance and decide which to use for what. - Survey the international supply situation for nuclear power plants, fuel, fuel cycle services and technology transfer, including technical, economic, political and policy aspects. - Review the possible organisational structures for nuclear activities, including ownership of nuclear power plants, radiation protection, nuclear safety, R&D, waste management, disposal and safeguards. - Review possible alternative nuclear safety policies (acceptance of supplier country's regulations or adoption of other alternative). - Review legislative requirements for ownership of nuclear power plants and material, radiation protection, nuclear safety and third party liability. - Review possible options for waste management and disposal, including the back end of the fuel cycle. - Assess the requirements and possible mechanisms for financing. - Assess the national infrastructure requirements, capabilities, constraints and development needs, in particular, with regard to qualified manpower at all levels, industrial support, QM/QA, management systems and support to technology transfer. - Define a group (or expand the existing one) to be responsible for public information on all aspects of nuclear power and prepare a programme for its work. - Survey sites for nuclear power plants and waste repositories and initiate site survey processes.	***TO REVIEW ALL RELEVANT ISSUES RELATED TO NUCLEAR POWER***
C. DEVELOPING THE NUCLEAR POWER OPTION	- Develop and propose a policy of the nuclear safety regime. - Develop and propose a policy for nuclear manpower development at home and foreign training. - Develop a realistic approach to setting targets for national participation in the first nuclear plant and develop proposals for the national infrastructure to support the nuclear options. - Identify the needs for international agreements and contracts, including non-proliferation aspects. - Propose a long-term policy for nuclear waste management and disposal, including the whole back end of the nuclear fuel cycle and siting of waste repositories, based on existing activities. - Summarise the benefits, disadvantages, requirements and constraints of nuclear power introduction in a "nuclear power plant pre-investment study", which must include all technical, economic, financial, social and environmental aspects. - Decide on an overall policy for nuclear power application in the context of national development plans and long-term electricity supply planning, including policies for safety, waste management and infrastructure development.	***TO DEFINE A NUCLEAR POWER POLICY***

STAGES	ACTIONS	OBJECTIVE
D. ESTABLISHING THE NUCLEAR POWER OPTION	- Establish the legal and organisational framework for plant ownership, operation and regulation. - Establish the regulatory body. - Establish an overall, preliminary timing of nuclear power plants within the electricity supply plan. - Define the possible and desirable national participation in the first projects. - Start negotiation of the international agreements required. - Start nuclear manpower development programmes. - Establish a project management group. - Launch a pre-investment study. - Start developing an adequate and stable electricity grid	***TO LAUNCH A PRE-INVESTMENT STUDY***

In any case, a comprehensive action plan where the responsibilities of different agencies are delineated will have to be developed and approved by the government right in the early stages of NPP project planning.

The organizations associated with nuclear power programme planning include:

- The **government** which, through its ministries, planning commission and other authorities, will have to take a lead role in creating the policies for energy supply, safety and regulation, environmental protection, domestic infrastructure development, including those related to education and training of nuclear manpower, and to the use of the international market. It will have to promulgate the necessary legislation, suscribe international conventions and protocols, establish the needed organizations or select the ones which should have important roles, and take the actions necessary to facilitate financing;
- The future **plant owner** who will have responsibilities for electricity system expansion planning, performance of economic analyses, defining the projects, obtaining licensing and executing them and operating the plants safely. If this organisation is different from the utility which owns and operates other generating plants, a close cooperation and coordination with the utility will be necessary in order to ensure a coherent operational plan for the nuclear and non-nuclear generation systems;
- The independent **nuclear regulatory body,** which may have to be created or expanded, with responsibilities for defining all safety, safeguards and security requirements and supervising that they are met.
- Other **regulatory authorities**, involved in specif areas such as safety of pressure vessels and electrical installationsk pollution control, environmental protection,etc.
- The different **R&D organizations**, including nuclear research centres, which have to give scientific and technical support and also promote and facilitate technology transfer;
- The **national industry**, which will participate actively in any NPP project;
- The **educational institutions**, which will have to help meet the needs for highly qualified staff at all levels.

4.6. Activities related with treaties, conventions and agreements

4.6.1. Preparation of conformity programme

Treaties, conventions and agreements related to the use of nuclear power for electricity production have been listed in 2.1 and Appendix I.

In the pre-project stage, the activities related to this subject will mainly consist in the understanding of the responsibilities born by a country using nuclear power and in the preparation of a conformity programme that would allow the country to meet its obligations under the terms of these treaties, conventions and agreements internally as well as internationally once a final decision is taken to use nuclear power as a source of producing electricity.

New laws or complementary ones as well as regulatory documents might need to be written and approved by the national government. In addition, the country will need to participate and sign specific agreements with countries of potential suppliers which might require long negotiations.

4.6.2. Accounting and control of nuclear materials

The introduction of a NPP normally commits a country to accept international safeguards (see 2.6). Relevant IAEA publications provide the basis for Safeguards Agreements between the IAEA and States pursuant to the NPT, or between the IAEA and States that did not ratify the NPT.

One of the basic requirements of NPT agreements conforming to INFCIRC/153 is that the State shall establish and maintain a system of accounting for and control of all nuclear materials, including periodical external inspections subject to safeguards. Safeguards agreements conforming to INFCIRC/66/Rev.2 do not explicitly call for States to establish and maintain a 'system' of accounting for and control of nuclear material, but the fact that the document calls for agreement between the IAEA and the State on a 'system of records' and a 'system of reports' implies the need for an accounting and control system. The establishment of a State System of Accounting for and Control of Nuclear Material (SSAC) is needed, whether or not such a system is explicitly required.

4.7. National infrastructure

Even if the approach of importing the first NPP on a turnkey basis is selected, there are certain basic national infrastructure requirements to be fulfilled. In fact, a NPP project could hardly exist as a lone case of advanced technology in a country without adequate infrastructures.

Organizational, manpower, regulatory, governmental, industrial, financial, legal and educational and training infrastructure requirements to support a NPP project are quite extensive. The infrastructure will have to be gradually built up as the NPP project evolves, but at the start of the programme some basic infrastructure is already required so that the studies of the first project can proceed smoothly [8].

A survey of the national capabilities should be performed to establish a clear understanding of the scope, schedule and costs involved in the development efforts, as well as of the pre-investment of achieving the required results taking into account the country's prevailing possibilities and constraints.

The lack of adequate national infrastructure and the effort and time required for its development may constitute the principal constraints to the implementation of a NPP project and could effectively determine the schedule for the introduction of the first NPP.

4.7.1. Long term nuclear power programme policy and commitment

The special features of a NPP require the establishment of organizational structures, highly competent personnel, national infrastructures and substantial financial resources. The deployment of important national resources can only be attained in the assurance of a firm commitment at governmental level to a clearly formulated long-term policy. Particularly the long-term aspect is important in creating the necessary confidence to attract investments and industrial support. In some countries the Government's nuclear policy and the commitment to its implementation has been promulgated as constitutional mandate.

A prerequisite to such a commitment is the establishment of a clear policy on the desired energy mix for the country and an assessment of the pre-investment of the potential use of nuclear power.

4.7.2. Science and technology

It is widely recognized that national development in general and nuclear in particular, require a scientific and technological infrastructure. Such infrastructure is mainly contained in:

- National and private R&D institutes;
- Institutes and laboratories for standardization and calibration;
- Higher educational institutions;
- Professional training centres;
- Scientific academies and professional associations;
- National industry.

Past experience of countries embarked on a NPP planning has indicated that the establishment of a nuclear research institute operating a research reactor, through not prerequisite for a NPP, has always proved to produce a catalytic effect upon the country's nuclear development.

An important role for the establishment of a nuclear R&D infrastructure is to stimulate the activities in various fields of nuclear science and technology, which will keep the experts active in their respective specializations. It also provides a good source of manpower in some important areas needed for NPPs, such as reactor engineering, reactor operation, radiation protection, radiochemistry, nuclear safety and waste disposal.

Management disciplines related with project management, including quality and business areas, are also required.

It is in general the government's role to take the lead in establishing a scientific and technological infrastructure for NPPs. Depending on the objectives of the national policies and the particular conditions prevailing in the country, this could be done by:

- Promoting technology-oriented applied R&D activities in general;
- Establishing national nuclear R&D institutes and nuclear technology development centres with adequate staffing, funding, facilities, programmes and autonomy;
- Introducing nuclear science and technology-oriented curricula in national universities or institutes of advanced science;
- Promoting the establishment of nuclear training centres according to the expected manpower development requirements;

- Concluding international agreements and arrangements for the exchange of scientific and technical information and the transfer of technology;
- Promoting and financing the specialized training of professionals within the country and abroad;
- Establishing a system of socio-economic incentives to provide motivation for professionals to choose scientific and technological careers in the country.

The development of a viable science and technology infrastructures is a long-term process which can take several years or even decades, depending on the level of the country's overall scientific and technological infrastructures at the beginning of this process.

4.7.3. Human resources development

A country embarking on the first NPP should make a critical and realistic assessment of its organizational, educational and industrial capabilities and determine the requirements for developing the quality and quantity of human resources needed.

Since nuclear technology has special features that are not encountered in other areas of industrial development, special requirements are imposed on manpower for NPP operation, fuel cycle activities, radioactive waste management and radiological protection. Early recognition of these special features will help in the definition of the actions required to meet the requirements.

The human resources development programme for each country has its own unique characteristics that should be identified and taken into account. This is only possible when national planners primarily develop the programme. General guidance, or outside expertise can and should be used wherever needed, but it should never supplant the country's own effort to define its human resources requirements from a thorough understanding of the nature of each activity and task in the first NPP project.

Governmental support is required for consistent, long-range policies on human resources development, and decisions and commitments must be taken at the governmental level. In a NPP project, whatever the contracting arrangements, there are certain essential activities, for which full responsibility has to be borne by national organizations and which have to be performed primarily by qualified local manpower. Therefore, before undertaking a nuclear NPP project, a country must be prepared and committed to develop its manpower in order to attain the capability to perform at least these essential activities [8].

4.7.4. Timely legal framework

Amongst the preparatory steps required for the implementation of a NPP project, it is essential that consideration be given at the earliest stage to the legal and administrative aspects thereof in order to achieve the timely establishment of an adequate legal framework. The legislation governing industrial establishments of a hazardous nature and, in particular, public utilities will have to apply to the erection of a NPP as well. However, the most stringent safety measures required because of the special nature of nuclear energy, and the effective financial protection to be ensured for victims of 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 and related matters should basically be aimed at ensuring that a national nuclear law is established which addresses, inter alia:

- Providing legislative authority for regulating and ensuring the safe development and use of nuclear energy in the national interests;
- Vesting a specific nuclear regulatory body with such a functional status and powers that would enable it to discharge its regulatory responsibilities independently of governmental, public and private corporations, manufacturers and suppliers;
- Setting forth the principles, conditions and procedures under which the regulatory body may authorize the carrying out of nuclear activities, with adequate physical protection of nuclear materials and facilities, with proper regard to protecting the environment, and in accordance with relevant treaty obligations entered into by the State; and
- Establishing the principles and rules consistent with international conventions on third party liability for nuclear damage in order to ensure adequate indemnification in the event of a nuclear incident.

Enabling legislation should, to the extent feasible, look forward into the future and accordingly provide a comprehensive framework encompassing foreseeable developments of nuclear energy applications within the national context. It should also, where appropriate, take into account approaches by other countries to the issues involved and relevant recommendations established by qualified intergovernmental organizations.

4.7.5. Financing

The availability of adequate and secure financial resources is probably one of the most crucial constraints affecting the implementation of a NPP project. Though the end product of a NPP is the same as the end product of a fossil-fuelled power plant, i.e. electricity, there are certain differences from the point of view of financing. These are mainly due to:

— The higher investment costs which may even exceed the overall credit limits of lending institutions for an individual country;
— The longer construction period than for fossil fuelled power plants;
— The potential uncertainties in schedule and costs due, for instance, to regulatory and public interventions, longer construction duration and policy changes.

Another factor that makes NPPs different from equivalent fossil-fuelled power plants is the level of management, technical and engineering skills that are needed. From the point of view of financing institutions, concern may arise regarding the competence of the owner to undertake such a complex operation, in particular for a first NPP. Because of all these differences, special financing approaches are required for NPPs to overcome the difficulties and constraints that may be encountered.

The total capital investment for NPPs is higher than for equivalent fossil-fuelled plants. In addition, the expansion and upgrading of the transmission and distribution systems may also prove necessary and require additional funds. Because of these higher initial financing requirements, the availability of the necessary funds might constitute difficulties in relation to the gross national capital formation, balance of payments and the priorities assigned to various development projects in the country.

The classical method of export credit financing by export-import banks has been used in many cases in the past. The capital costs for power plants can, however, be so high that, even for coal-fired plants, international financing consortia are formed to share the financing risks for a single plant.

It may well be that the government could find itself having to make a choice between available credits being used for a NPP or for other high priority development projects, even if the latter would bring less economic benefits over the long term. This emphasises the need to perform financial analyses from the very beginning, in parallel with the economic studies of different system expansion strategies, in order to provide the basis for such priority setting.

An overriding consideration for the lending institutions is the creditworthiness of the country and the plant owner. This depends in part on the past performance in servicing loans but also on how realistically the tariffs for electricity have been set. The World Bank and other lenders are highly critical of subsidised tariffs, which do not reflect real costs of production.

An appropriate risk analysis should address, among others, the following factors influencing financing:

- Is the nuclear regulatory estability ensured?
- Is the NPP option financially viable as well as economically competitive?
- Is the plant owner organisation financially sound?
- Do the country and plant owner have acceptable credit ratings?
- Are the generally less favourable credit conditions for NPP supportable or are there sources, which would be more acceptable?
- Is the currency risk covered?
- Is there a government guarantee?
- Do electricity tariffs reflect full cost recovery in a deregulated market?
- Can financing of local costs be arranged?
- Are there other, high priority and competing, national development needs?
- Has the utility the capability to collect generation costs?
- What are the conclusions of the environmental assessment?

One of the most difficult, but often underestimated, problems is arranging for local financing. This is not covered by outside financing sources and must at the very least cover the costs of local participation in the project. Sources of local financing would be the government budget and owner's funds, either from equity or earnings set aside for investments. Difficulties arise if there is a shortage of government funds and if there are constraints in the local capital market. If such problems exist, they must be recognized clearly and early on before any policy decisions on a NPP are taken.

The question on the possibilities to obtain financing on supportable terms thus remains one of high priority, which must be followed carefully from the very beginning, when the NPP option is included in the planning process. It will require using a group having expertise to deal with financial, economic and legal questions.

4.8. National participation plan

The introduction of the first NPP in most countries will be initially and may remain for some time based largely on the importation from advanced supplier countries. However, national participation is an essential element in the development of a NPP project. The extent of such participation will significantly depend on the existing infrastructures capabilities and on the availability of local resources for the supply of necessary materials, services, equipment and qualified manpower.

While interest in the maximum use of domestic resources in any industrial activity is a common characteristic of all countries, the degree of national involvement in NPP development will be a process in which the local participation is gradually increased in the further NPP projects. This will be possible if there is a policy favouring the evolution of the national capabilities for such participation, f. ex. through technology transfer agreements, in various areas of nuclear technology development of local suppliers (detailed engineering, mechanical/electrical erection, etc).

4.8.1. National industry

There are no firm rules regarding the industrial infrastructure needs of a country starting a NPP project. One element that is of prime importance is the quality requirements that are looked for to ensure the safe operation of the NPP. At minimum, the plant has to be built, the equipment and components have to be installed and tested, and the plant has to be licensed, operated and maintained within the country. This means a basic level of competent construction and erection firms and of operation and maintenance capabilities. The available industrial infrastructure will probably not have all the technology, know-how, level of quality, or the expertise necessary for the NPP, but these can be acquired. Regarding engineering industrial capability, this becomes a basic requirement if a non-turnkey approach is adopted, or if there is a policy for increased national participation.

The national engineering, manufacturing, construction and erection capabilities play an essential role in the promotion and development of the NPP project. These industrial infrastructures should be closely associated, early on, with the NPP project planning to which they provide a pool of necessary skills and human resources. The quality requirements of the nuclear technology call for the enforcement of an adequate QA programme (sometimes also named quality management (QM) programme).

A NPP project places special demands on the industrial infrastructure, for example:

- Advanced technology is involved, which usually has to be acquired through technology transfer from foreign suppliers;
- Strict quality standards have to be met, owing to nuclear safety and reliability requirements;
- Unfamiliar industrial standards have to be applied;
- Some special materials new to the industry are used;
- Some supplied items are of unique design;
- Equipment and components of unusually large sizes and weights and hazards have to be handled and transported.
- Schedules must be rigourosly complied with due to large investment costs;
- Cost has to be maintained at a reasonably competitive level;

The overall result is that the existing conventional industry is usually unable to supply the materials, equipment, components and services without first improving its capability. This means upgrading of QA programme, acquisition of new technology, installation of additional equipment and changes in methods and procedures. All these imply generally an increase on their financial requirements.

4.8.2. National involvement

There are certain activities within the scope of a NPP project, for which full responsibility has to be borne by national organizations and which should be primarily executed by national manpower whatever the contracting arrangements. These are considered essential or basic activities for national participation. Expert help from abroad could be obtained and used-up to a point, but only for technical assistance and not as a complete replacement of the national effort. Categorization of activities as essential or basic is particular to a country; there are, however, some general indications based on experience which should be considered when planning the national effort [8].

In general, most activities to be performed during the pre-project stage would be basic activities for national participation. A country expecting to have a successful NPP project must be able and willing to study, plan and prepare its first project and make all necessary decisions itself. Should it lack resources to perform these activities, serious considerations should be given as to whether the country ought to embark on a NPP or postpone it until such resources are available.

The first target for national involvement would be to adequately perform those activities that have been defined as basic for national participation. Further, short-term development of those capabilities required to perform the activities set out in the priorities above would be objectives to be progressively attained in the project. This would call for increasing responsibility of the owner for project management and development of national engineering services, as well as the enhancement of manufacturing capabilities and improvement of quality in their production lines. Such a course of action would allow the initial turnkey approach (if adopted) to evolve into a split-package approach and eventually give possibility to move to a multi-package management of the project. This evolution is a challenging task for the country, and requires a firm long-term policy for the NPP project, careful planning and realistic and critical assessment.

From the very start of the NPP project planning, the importance of national participation must be fully appreciated. One of the essential factors defining the project viability will be the extent to which the industrial capabilities are available and can be made available in the country. This is the factor to account for and the ground on which the decision of whether embarking on a NPP should be formulated. Right at the start of the decision-making process the responsible authorities must take stock of the situation with a thorough survey of national industries and realistic assessment of their present and future potential capabilities.

The survey should first of all identify those national industries whose production meets or might meet the quality standards of nuclear technology. Investments, if needed, associated with their necessary development must be evaluated on a cost/benefit basis. This activity best starts with an assessment of the present engineering and industrial capability and its participation in conventional power projects and even in other large projects. This may lead to a plan to improve the local participation in these projects that would not only save foreign currency but also be a good means to prepare the local engineering and industry for its future participation in a NPP project [12].

The first NPP project is usually executed on a turnkey contract basis with the supplier, but in the past it has been a normal demand by the plant owner that national engineering and industry be used to the extent possible and a plan has often been made aiming towards an increasing participation in subsequent projects. The decision is important, since realistic targets can help in the effective transfer of imported technology to the domestic industry but overly ambitious targets can lead to serious delays in the projects. Whether the project is executed on a turnkey basis or not, the licensing process demands a deep involvement of the future operator for the application of the construction and operation licenses. The regulatory body also needs the necessary technical capabilities in order to effectively assess the applications prior to delivering the licenses.

4.9. Site survey

The site survey includes the activities conducted at national scale directed to identify potential candidate sites that are suitable for a NPP. The identification, selection, evaluation and authorization of suitable sites for NPPs require extensive studies. Preliminary sites surveys are required to provide the necessary basis for site selection and the input to the electric system expansion planning studies. Therefore, a reasonable number of alternatives should be identified and investigated in sufficient depth to enable preliminary decisions to be reached as to their suitability and to assess their implications.

4.9.1. Site survey scope

The site studies will include:

- Ease of integration into the electric system;
- Geology and tectonic;
- Seismology;
- Heat removal capability;
- Hydrology;
- Demography;
- Meteorology;
- Nuclear safety and radiation protection aspects;
- Environmental effects;
- Risks from man-made events;
- Availability of local infrastructure;
- Ease of access;
- Legal aspects;
- Public acceptance (including in neighbouring countries if the site is close to a border).

The studies might well be carried out largely on the basis of existing data and information. Sites identified require to be characterized in order of merit. In principle, it can be assumed that suitable sites can be located in any given country but site characteristics can affect substantially the cost of a NPP.

A site survey may be subdivided into three distinct stages:

- Regional analysis and identification of potential sites;
- Screening of potential sites and selection of candidate sites;
- Comparison of candidate sites.

In each of these stages, those relevant site characteristics are considered that may lead to the rejection of unacceptable areas or sites, and to the identification of the more suitable ones. The details of the data required and the complexity and sophistication of the selection process increase as the site survey advances towards its goals of selecting the preferred sites. It must be recognized that the quantity and quality of information to be collected during the various stages vary in relation to the site characteristic under consideration.

It is necessary to establish for each region:

- The characteristic to be considered at each stage;
- The criteria for rejecting areas and sites;
- The criteria for assigning a weight factor to each characteristic of the sites;
- The comparison methodologies.

4.9.2. Environmental assessment

Environmental assessment and other impacts of different energy options should be included in the NPP project planning study. In the case of NPPs, at least the specific aspects of possible radiation impacts are included in the preliminary safety analysis report. The environmental assessment should determine if more than one NPP can be constructed at the site in the future, reviewing cooling capacity and potential temperature increase of heat sinks. Potential exclusion radio for the NPP and future units should be evaluated and defined, in order to determine possible necessary future land.

4.9.3. Public acceptance

A NPP project is a national undertaking and hence its introduction and implementation within the country, including the acceptance by the population in general, is a matter to be handled primarily by national (and regional) governmental organizations and authorities. The electric utility, which is providing a public service, also has an important role to play. A public information programme aimed at both the general public and the population around the site of the NPP should be carefully planned and implemented and started as early as possible.

The justification of the NPP project should be explained in terms of its economic viability, its contribution to energy independence and how it fits with economic development plans on a national level, and its impact on economy, development and employment on a local level.

Among the basic facts to be discussed openly are also the role of environmental and health issues, waste management and disposal policies and information on potentially harmful consequences of normal operation of NPPs and of abnormal events. These should be discussed in simple terms. However, each interaction should be tailored to the particular stakeholder group with whom it interacts. A preoperational fingerprint programme for future evaluations of environmental impact during the NPP operation should be made available to the public and regulators (waterborne concentrations and biota concentrations evolution, routinely air and water monitoring, etc)

4.10. Manpower needs for pre-project activities

Pre-project activities require relatively few but highly qualified professionals. It should be noted that all pre-project activities are considered essential for national participation. Since these activities overlap quite a bit, there is a need for particularly close cooperation and transfer of data and findings. Experienced staff should be used quite flexibly in this early stage, more in a task force style than in a rigorous organizational structure. Many times such staff could be employed on either side of the line dividing adjacent tasks and activities. Quantity is not and cannot be made a substitute for knowledge and experience. For all these activities, quality is essential.

4.11. Selection of a consultant(s)

Generally, it is good practice to establish a short list of consultants containing from three to six candidates. Some of the key factors to be considered in the selection of a consultant are:

- General and relevant experience;
  - Sufficient experience in the past in the relevant works;
- Capacity to complete the work;
  - Experience of key personnel such as project management and senior staff;
- Access to support resources;
- Past performance on client contracts;
- Meaningful partnership/associations with local firms;
- Quality management system established in the firm.

5. PROJECT DECISION-MAKING STAGE

To allow for judicious decision-making, many elements particular to a country or to a specific organization will have to be reviewed carefully. This stage can be described as preparatory activities to support the launching of a NPP project and to lead to the decision-making to go forward with it. As for any other stage in the NPP project, all the activities are accomplished in compliance with the established management system that provides the framework of the arrangements and processes to address all the goals of the NPP project (see 2.8).

Once nuclear power has been established as a viable alternative to other energy sources and a need for the development of a NPP project has been indicated through the NPPPS, the next step would be the detailed in-depth study of the first NPP to be implemented.

For this purpose, a pre-investment (feasibility) study for the detailed definition and assessment of a specific NPP must be undertaken as well as a site evaluation, both of which are part of this chapter.

5.1. Pre-investment study

5.1.1. Objectives of a pre-investment study

The pre-investment (feasibility) study is primarily intended to provide the relevant interested parties (governmental authorities, utility/owner, stakeholders) with all the necessary detailed information needed to decide on the implementation of the NPP project. It will also be of importance in the negotiations for financing of the project, as it is usually requested by all financing institutions.

Although the content and scope of a pre-investment study may vary depending upon the particular associated conditions, the basic objectives will include the following:

- Evaluate in detail the integration of the NPP to the electric power system;

- Determine the size and main features of the NPP;
- Determine the preferred site and identify any specific problems associated with the selected site (might be a separate study or part of the pre-investment study;
- Determine which type (or types) of reactor should be the basis of bids;
- Carry out detailed cost and economic evaluations and compare with alternative options;
- Determine the organizational and manpower requirements to implement the project and to operate the plant;
- Determine the overall project schedule;
- Determine financial viability for the project (the project is self-sustainable from the financial point of view) and the possible sources for financing;
- Determine the contractual approach to be adopted for the acquisition of the plant;
- Analyse the international market for NPPs, fuel cycle and essential materials and services;
- Define the country's infrastructure requirements and survey the national participation possibilities;
- Define the nuclear safety criteria to be applied.
- Assess the environmental impact.

5.1.2. Scope of a pre-investment study

The scope of a pre-investment study should provide a detailed analysis and information on all technical, economical, financial, regulatory, etc. aspects, with specific recommendations to enable the authorities concerned to make the appropriate decisions for the implementation of the NPP project. It should also outline the further steps to be taken and identify the areas in which more investigations are still needed.

5.1.2.1. Contents of a pre-investment study

An example of the contents of a pre-investment study is given in Table 2.

TABLE 2 CONTENTS OF THE PRE-INVESTMENT (FEASIBILITY) STUDY REPORT (REF. [10])

1. INTRODUCTION 1.1 Objectives 1.2 Scope 1.3 Background information 1.4 National energy market analysis	2. ELECTRIC SYSTEM ANALYSIS 2.1 Electric system description 2.2 Demand forecast 2.3 Generation expansion programme
3. CHOICE OF UNIT SIZE 3.1 Electric supply grid analysis 3.2 Unit size definition 3.3 Station size	4. SITE CONSIDERATIONS 4.1 Site survey 4.2 Site selection and evaluation

5. TECHNICAL ASPECTS OF NUCLEAR PLANTS 5.1 Nuclear power supply market survey and choice of reactor types 5.2 Design characteristics 5.3 Construction schedule 5.4 Fuel cycle evaluation	6. NUCLEAR COST ESTIMATES 6.1 Basis of cost estimates 6.2 Capital costs 6.3 Fuel costs 6.4 Operation and maintenance costs
7. GENERATIONS COSTS 7.1 Annual changes 7.2 Total generating costs 7.3 Cost estimates and comparison of alternative sources	8. FINANCIAL REVIEW 8.1 Financial review of utility/owner 8.2 Financial requirements of nuclear project 8.3 Financial projections for utility/owner 8.4 Survey of financing sources
9. PROJECT DEVELOPMENT 9.1 Project organization 9.2 Project development schedule 9.3 Contractual approach 9.4 Safety criteria 9.5 Legal framework	10. STAFFING AND TRAINING REQUIREMENTS 10.1 Project management 10.2 Construction 10.3 Commissioning 10.4 Operations and maintenance 10.5 Industrial infrastructure
11. NATIONAL PARTICIPATION 11.1 National participation policy and strategy 11.2 Survey of industrial infrastructure 11.3 Participation goals and implementation measures	12. CONCLUSIONS AND RECOMMENDATIONS 12.1 Pre-investment of nuclear power project 12.2 Implementation programme

5.1.2.2. Organization and staffing necessary for the preparation of a pre-investment study

To perform an interdisciplinary pre-investment study basically ten to fifteen professionals from the Nuclear Power Implementation Agency (see 4.1 and [8]) would be required to form a team, assisted part-time by experts (advisers, consultants) in specific subjects. It is essential that sufficient resources and experienced people be made available for performing the study.

Some of the personnel involved in the NPPPS would logically expand their work into this activity and would form a team with other professionals who could have gained their experience in non-nuclear projects. The performance of a pre-investment study requires a year to a year and a half, not including site survey and evaluation, which would be an on-going activity during the course of the pre-investment study.

5.2. Site selection and evaluation

All the potential sites identified during the site survey are evaluated in order to select the definitive site for the NPP. Requirements for site evaluation are to ensure adequate protection of site personnel, the public and the environment from the effects of ionizing radiation and other factors arising from nuclear installations. The IAEA Safety Standards ref. [13] establishes requirements and provides criteria for ensuring safety in the site evaluation of nuclear installations. The related IAEA Safety Guides provide detailed guidance on fulfilling the requirements.

The purpose of site evaluation is to demonstrate that the preferred sites are acceptable from all aspects, and in particular from the safety point of view. The site-related design bases are evaluated and defined before the start of the plant design.

After the start of construction and prior to operation, additional studies and site investigations are performed, to complete and refine the assessment of site characteristics, as needed for plant operation, and in particular for developing emergency plans for the case of potential accidents.

5.3. Socio-economical and cultural aspects

The construction and operation of a NPP involves several non-safety related factors that influence local population. In areas of high unemployment a power plant may generate a significant number of jobs during the construction stage. On the other hand, the work force associated with the plant place demand upon the local infrastructure resources (housing, schools, and community). It is desirable those adverse social impacts of the plant, if any, are minimized and that social benefits are enhanced.

The construction and operation of a power plant also generate traffic causing noise, and visual effects. It may also disturb or limit the access to important archaeological remains if there are any, and it may modify the landscape. Should these affect individuals or communities, the government and local or regional organizations should provide forums for discussion in order to move towards acceptable solutions for most of the individuals and for general interest.

The socio-economical and cultural aspects components of the project on the environment should include, but not necessarily be limited, to:

- population (including relevant demographic characteristics);
- economic base;
- community infrastructure and services;
- renewable and non-renewable resource use;
- existing and planned land use;
- heritage, cultural or archaeological sites;
- recreation areas; and
- use of lands and resources for traditional purposes by aboriginal persons.

The required level of detail in the description of the existing environment will be less where the potential interactions between the NPP project and various components of the environment are weak or remote in time and space. Relevant existing information may be used to describe the environment. Where that information is significantly lacking, additional research and field studies may be required to complete the site related and site-installation interaction factors.

5.4. Implementation of the conformity plan related to legal framework

The implementation of a NPP project requires the timely establishment of an adequate legal framework. As the work progress during the decision — making stage, all activities related to legal requirements have to be integrated to the work load of the owner's management organization.

Before an invitation to bid, the necessary legal frameworks must be in place including treaties, conventions and agreements which need to be taken care of with the same time consideration as above. Non-proliferation treaty, international safeguards, physical protection and protection against terrorism, international cooperation and trans-boundary conventions are some of the elements to manage with due regard to time.

5.5. Contractual approach

Nuclear power plants have been contracted in a wide variety of ways. At one extreme, a single contractor has been given complete technical responsibility to design, build and commission a complete NPP, handing it over to the owner only when it is running. At the other extreme, the owner has bought only the basic hardware of the nuclear steam supply system (NSSS) from the reactor vendor, designing the rest of the power plant station and buying all of the other equipment himself.

5.5.1. Types of contractual approach

Basically, there are three different types of contractual approach which have been applied so far for NPP stations, namely:

- Turnkey approach, where a single contractor or a consortium of contractors takes the overall technical responsibility for the whole works;
- Split-package approach, where the overall technical responsibility is divided between a relatively small number of contractors, each building a large section of the works;
- Multi-contract approach, where the owner or his architect-engineer (A/E) assumes overall responsibility for engineering the station, issuing a large number of contracts.

The possible lead technical responsibilities for the different types of contractual approach are shown in Table 3.

TABLE 3 USUAL LEAD TECHNICAL RESPONSIBILITIES FOR DIFFERENT CONTRACT TYPES (REF. [14])

Activity	Lead responsibility		
	Turnkey	**Split package**	**Multiple package**
Pre-project activities	U	U	U
Project management	MC	AE or U	U + AE
Project engineering	MC	AE + SS	U or AE
Quality assurance	MC + U	AE + SS + U	U + AE
Procurement	MC	AE + SS	U or AE
Application for license	U	U	U
Licensing	RA	RA	RA
Safeguards, physical protection	U	U	U
Manufacturing	MC	SS + EM	EM
Site preparation	U or MC	U or AE	U or AE
Erection	MC	AE + SS	U or AE
Equipment installation	MC	AE + SS	U or AE
Commissioning	MC	AE + U	U or AE
Plant operation and maintenance	U	U	U
Fuel procurement	U	U	U
Fuel fabrication	FS	FS	FS
Waste management	U	U	U

Symbols: AE : Architect-engineer; EM Equipment manufacturer; FS : Fuel supplier; RA : Regulatory authority; MC : Main contractor; SS : System supplier; U : Utility

5.5.1.1. Turnkey approaches

Basically, there are two types of turnkey approaches; super turnkey and normal turnkey.

- *Super turnkey*

This term is used when a single contract is placed covering the whole NPP. It also implies that the prime technical responsibility for the success of the project and, therefore, also for the design of the plant, is placed upon the contractor. This approach is particularly suitable for utilities with limitations in manpower resources and/or experience in the nuclear field.

- *Normal turnkey*

This term is used to describe a contract placed for a NPP where the utility supplies all peripheral items of the plant (10-20% of the plant costs). It is usual for owners with nuclear experience or greater competence in conventional power stations to wish to influence and approve the design of the plant to a greater extent than for the super turnkey contracts, as well as taking full responsibility for the owner's scope themselves. The owner's scope can, however, differ substantially depending on the engineering capability within the utility.

5.5.1.2. Split-package contracts

The split-package approach has been applied to a great extent for the construction of NPPs and also for conventional thermal power stations, where the term 'package' is used herein to describe a functionally complete part of a power station where a single contractor takes the overall responsibility for the design, supply, construction and setting to work.

Basically, one distinguishes between the following types of split-package approaches:

- *The two-package approach*

With this approach, the two main contracts (excluding the owner's scope) are for a nuclear island and a turbine island. By dividing the main plant into two packages, a higher degree of competition and technical choice can be affected. This approach has, however, two main difficulties: one the problem of harmonizing the interfaces, and the other the problem of having two civil contractors close to one another. However, this can be avoided if each bidder is asked to select his civil contractor later by a sequential bidding technique. The bidding for the civil contractor is for both halves of the station.

- *The three-package approach*

This approach separates the civil works from both the nuclear and turbine islands and makes them a separate contract placed directly by the owner. This approach has, apart from the problem related to civil work, the same positive and negative features of the two-package approach, i.e. it does not ease the problem associated with the interface between reactor and turbine. Considerable engineering and interfacing experience by the utility is required.

- *The five-package approach*

In this approach the problems associated with the matching of the interface between the nuclear island and turbine island are reduced by the owner taking direct responsibility for much of the mechanical and electrical equipment which links them. The initial bidding is then for nuclear and turbine lots each with reduced extents of supply compared with the corresponding island. When the two main plant contractors have been chosen, the owner (or his architect-engineer) issues appropriate bid invitations for civil, mechanical and electrical lots to complete the power station. In practice the electrical and mechanical lots may be treated as a number of separate contracts over an extended period of time.

5.5.1.3. Multi-contract approach

The owner, or more usually his architect-engineer, invites bids for a the nuclear steam supply system (NSSS) and turbine-generator and fuel, selects the preferred bids, places contracts and then designs the balance-of- plant (BOP) around this equipment. The Architect/Engineer (A/E) will provide experienced and readily available staffs, which acts on the orders of the utility. The utility or its A/E will produce a very large part of the safety report and supervise construction, usually erecting the plant themselves.

5.5.2. Selection of the type of contract

The selection of the type of contract is one of the basic decisions to be taken concerning the realization of a NPP station. It should, therefore, receive great attention and be based on a careful analysis of all aspects. These aspects include:

- Potential vendors and their particular experiences and attributes;
- Standardization and proven quality;
- Government and industrial relationships;
- Competitive and economic considerations;
- Foreign financing possibilities;
- Guarantee and liability considerations;

- Planning and implementation of the project and subsequent projects;
- Availability of qualified project management, co-ordinating and engineering manpower;
- Development of national engineering and industry capability; and
- Owner experience in handling large projects.

Independently of the type of contract selected, provisions should be contractually arranged on transfer of design information and as-build plant information in order to ensure the procurement of replacement components and maintenance services after the NPP started operation.

5.6. Bid invitation specifications

The primary purpose of the bid invitation specifications (BIS) is to provide information to the bidders (the prospective suppliers). The prospective plant owner informs the bidders of his wishes and requirements, the conditions and circumstances under which the supplier will have to perform his tasks, the information required the form of presentation of this information in the bids and the basis on which the bids will be evaluated. The owner also makes proposals for contractual arrangements with the successful bidder. A diagram of the complete bid process is shown in Figure 2.

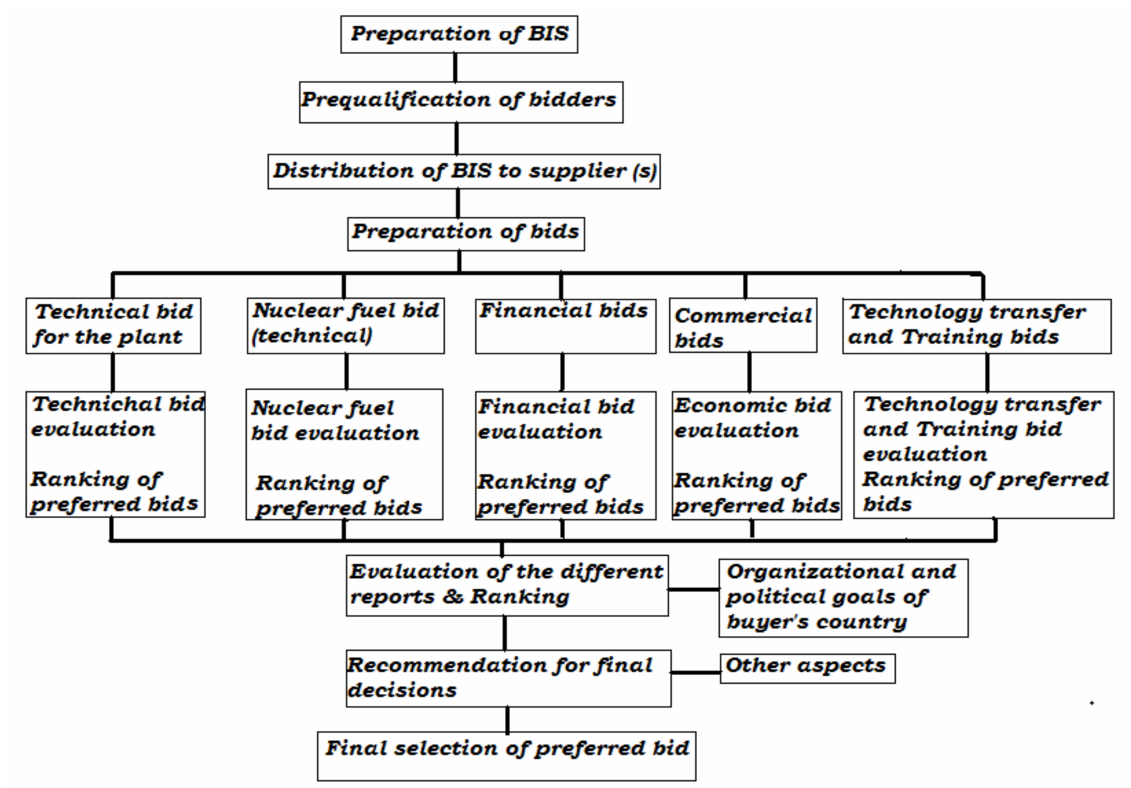

Fig. 2 Example of a bid process (Ref. [15]).

5.6.1. Organization and staffing necessary for BIS preparation

The owner of a NPP should have full responsibility for the preparation of the BIS and for its contents. He can delegate certain tasks, obtain assistance and use as much advice as he needs or wishes, but he should not delegate the general responsibility nor should he share it with anyone. The owner should establish a basic organizational unit which is in charge of the preparation of the BIS and should select competent persons for this unit.

The owner might request assistance from well qualified consultants or an A/E who has the experience and specialized knowledge that may be lacking in the owner's team. Consultants or A/E should, however, always have an advisory function. The overall effort required for preparing the BIS for a NPP under a turnkey contract is of the order of 10-20 professional man-years (including the basic team and outside assistance) and the time needed is about 8-12 months. For a split package project, considering the main packages, the overall effort and time needed may be somewhat higher but should be of a similar order of magnitude as those for a turnkey project.

5.6.1.1. Contents of the BIS and preparation procedures

The BIS should contain all the information needed by the bidders for the preparation of their bids, in response to the invitation of the owner and according to his requirements. This information should be structured in such a way as to facilitate the subsequent bid evaluation.

The example approach is to divide the contents of the BIS into two main parts. In each part, the different aspects and subject areas are treated separately, in a sequence which can facilitate the work.

5.6.1.2. Contents of the BIS

BIS is typically made of two main parts. The content of each part can be as follows:

Part 1: Information provided by the owner

1. Invitation letter
2. Administrative instructions
3. General information
4. Technical requirements and criteria including safety and security constraints
5. Scope of supply and services
6. National participation and technology transfer
7. Bid evaluation criteria
8. Draft contract: Terms and conditions
9. Commercial conditions

Part 2: Information requested from the bidders

1. General information
2. General technical aspects
3. Technical descriptions
4. Scope of supply and services
5. Alternatives and options
6. Quality assurance programme/Management System
7. Training
8. Project schedule
9. National participation and technology transfer
10. Guarantees and warranties
11. Deviations and exceptions
12. Commercial conditions

5.6.2. Bid evaluation

This section refers to the evaluation of bids for turnkey nuclear power plants but can also be applied for non-turnkey projects (nuclear steam supply systems and turbo-generator sets). It deals with the objectives and the basis for technical and economic bid evaluation as well as with the scope, methods and approaches which can be selected for such evaluation.

5.6.2.1. Technical bid evaluation

The technical bid evaluation is a part of the overall, bid evaluation, which comprises technical (including safety), economic, financial, contractual, political, organizational and other applicable aspects which have to be considered in the decision-making process of implementing the project and the selection of the suppliers.

Objectives of technical bid evaluation

The objectives of technical bid evaluation are to evaluate the bids with regard to scope and limits of supply and services as well as the technical design features of the plant offered. This is so as to determine the costs for deficit and surplus materials and services, the technical acceptability of a bid and/or the best technical bid.

In most instances the objective of the technical bid evaluation is to determine the technical acceptability of the bid rather than to determine the best technical bid. This is in particular the case if there is no open bidding competition (negotiated contract) and in cases where financing of the project is an important prerequisite for its realization.

A bid is technically acceptable if it gives assurance of an adequate standard of reliability and safety. The NPP must be licensable in the country and should further give assurance of adequate operability and maintainability.

The main aim in evaluating the technical acceptability of a bid is:

- To spot technical inadequate solutions;
- To evaluate the risks (in terms of performance and safety) associated with the construction, operation and maintenance of the station.

Basis for the technical evaluation

The main references for the technical bid evaluation are:

- Bid specifications prepared by the utility and/or its consultant;
- Bid documents prepared and submitted by the bidders;
- Reference plants;
- Preliminary safety analysis report (PSAR) of a reference or generic plant;
- Survey of the bidders;
- General project situation and related documents.

The best basis for a good technical evaluation is given if detailed bid specifications are available and the background of the bidders (reference plants, PSAR, survey of bidders) as well as the general project situation is adequately taken into account.

Scope of the technical evaluation

The scope of the technical bid evaluation depends on:

- The contract approach selected for the project (turnkey or non-turnkey) and the corresponding scope of the bids, including the determination of the balance-of-plant costs;
- The definition of technical bid evaluation as part of the overall bid evaluation (including organizational and contractual aspects).

Further, the scope and the depth of the technical bid evaluation are defined by the know-how and experience as well as the corresponding amount of money and time which are available for the evaluation.

Technical evaluation method

The technical evaluation of the bids mainly comprises:

- An evaluation of scope and limits of supply and services;
- An evaluation of the technical design features.

The evaluation of scope and limits of supply and services finally results in a cost estimate for any deficit or surplus material and/or services (compared with what has been specified in the bid specification) and gives directly an input into the economic bid evaluation (adjustment of the bid price).

The evaluation of the technical design features can finally result in a cost estimate, but might also be expressed only qualitatively. Design features which have a direct influence on station performance such as power output, efficiency, etc. can be and should be expressed in money terms.

Technical evaluation approach

The technical evaluation approach is the procedure followed by the owner to evaluate the bids, e.g. if a detailed evaluation is carried out on one bid, on a limited number of preferred bids, or on all bids received.

One distinguishes basically the following three types of evaluation approach which are applied for the technical evaluation of bids for nuclear power stations:

- Single evaluation approach;
- Two-stage evaluation approach; and
- Multi-evaluation approach.

The evaluation approaches differ mainly in the number of bids which are evaluated in detail. Simple evaluation approach is applied in the case of a negotiated contract approach with one particular bidder who, for technical and financial and/or political reasons, has been selected as the potential supplier for the plant. The two-stage evaluation approach is applied in connection with an open or limited bidding competition whereby, after a first evaluation dealing only with the important features, if possible, a short-list of one to three bidders is made, who are then evaluated in more detail. A multi-evaluation approach is applied in connection with an open bidding competition and it means that all bids which have been received are considered and evaluated to the same extent.

Technical evaluation work process

The technical bid evaluation has to be planned as part of the overall bid evaluation and as part of the overall project schedule. The work process required to prepare and organize the technical evaluation of bids for nuclear power projects comprises:

- Establishment of the evaluation method and approach;
- Preparation of a time schedule for the whole evaluation period;
- Preparation of an evaluation form and other standard forms; and
- Organization and instruction of the evaluation team.

The technical bid evaluation starts with the receipt of the bids and ends with the final evaluation report. The most important activities during the bid evaluation stage are the following:

- Receipt and opening of the bids;
- Preliminary bid evaluation and preparation of preliminary bid evaluation report;
- Detailed bid evaluation;
- Preparation of questionnaires;
- Negotiations;
- Preparation of input data for the economic bid evaluation including BOP cost estimate;
- Preparation of final evaluation report.

5.6.2.2. Economic bid evaluation

An example flow diagram of the complete economic bid evaluation process for an NPP is presented in Fig. 3. The first step necessary to obtain offers from suppliers involves the preparation of the BIS. In these specifications, the organization of the entire project should be explained in detail so that it is clear to the supplier(s) what the buyer wishes to purchase. The type of contract for plant construction — turnkey contract, split package contract or multiple package contract — must be clearly specified.

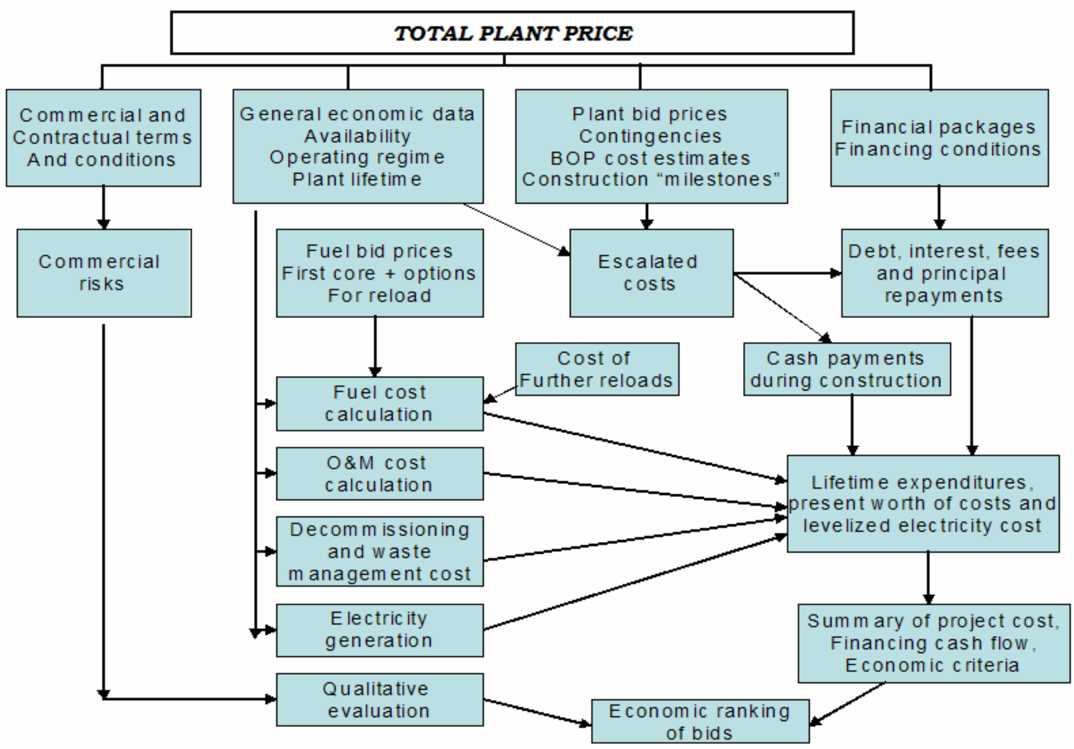

Fig. 3 Example data flow diagram of the economic bid evaluation process for NPPs (Ref. [15]).

Objectives of economic bid evaluation

The main objectives of the economic bid evaluation are to establish the plant costs and to rank the available bids with the help of an economic figure of merit. This requires consideration of the following points:

— Results of the technical bid evaluation;
— Capital investment costs;
— Nuclear fuel cycle costs;
— Operation and maintenance (O&M) costs;
— Owner's costs;
— Commercial and contractual terms and conditions;
— Financing proposals;
— Economic parameters;
— Domestic participation and technology transfer;
— Fringe benefits and spin-off effects;
— Political and socioeconomic aspects.

Basis for the economic bid evaluation

The economic bid evaluation is based on the following data and information.

— Cost information tabulated in accordance with an account system, such as:

- NPP investment costs, or for a reduced scope of supply (single components or systems) as specifically addressed in the BIS;
- Nuclear fuel cycle costs;
- O&M costs.

— Result of the technical bid evaluation, including cost estimates to account for technical differences;
— Commercial and contractual terms and conditions;
— Economic parameters;
— Financing proposals (local and foreign portion);
— Domestic participation and technology transfer (the local investment costs for industry, education of staff, infrastructure, authorities, research and development, and others may be calculated separately);
— Owner's costs.

5.6.2.3. Technical bid evaluation and interfaces with the economic bid evaluation

The technical bid evaluation provides the basis for the development of costs related to deficits or surpluses in materials and services occurring when a bid is compared with the BIS or the reference bid (the most complete one). Furthermore, cost figures have to be generated for technical deviations in the designs presented in the different bids.

Another important aspect of the evaluation process is the impact of differences in plant design and operating characteristics. One of the most difficult tasks is the assessment of differences in such diverse items as:

— Safety requirements;
— Failure criteria;
— Redundancies and diversities in components and systems that mitigate external or internal incidents or accidents;
— Radiological impacts on operating personnel and the plant environment;
— Implications of measures against "beyond design basis accidents"; and
— Probability figures for the occurrence of severe accidents.

Figure 4 illustrates the link between the technical and the economic bid evaluation. However, face to face contacts and exchange of interface information between the economic evaluation team and the other evaluation teams need to be very active and vigorous.

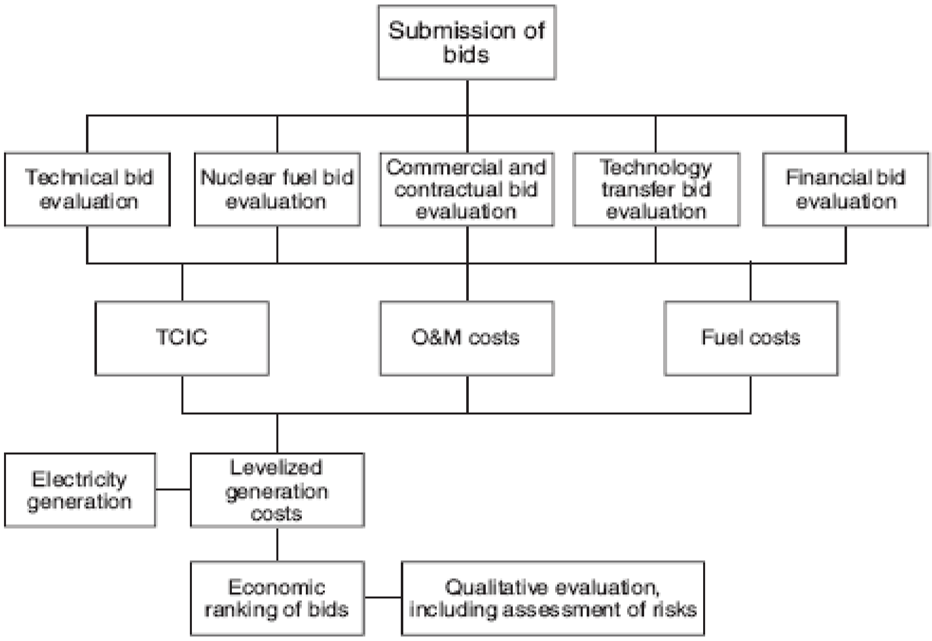

Fig. 4 Interfaces among the various fields of evaluation (ref. [15]).

5.6.3. Financing plan

A financing plan includes the collection of relevant data (as a function of time) on project related factors. These comprise the total capital investment, the nuclear fuel cycle costs with front end and back end components, the respective local and foreign portions, the establishment of debt/equity targets and the assessment of potential financing sources.

5.6.3.1. Financing sources

Financing of a NPP project is typically done through multi sourcing, a combination of export credits, commercial loans and owner’s resources. For a traditional financing arrangement in the construction of a NPP, the principal sources of local financing may include:

- Owner’s resources;
- Domestic bonds issues;
- Domestic loans from local banks credits;
- Credits from public entities;
- Funding from local government budget; and
- Local suppliers.

For the foreign scope, the principal financing sources are:

- Export credit agencies;
- Commercial banks;
- International development agencies;
- International bond markets; and
- International suppliers.

In the event that the above financing sources are insufficient to cover the projected cost of the NPP project, other financing mechanisms or arrangements must be considered. Some of these arrangements are:

- Project financing;
- Multi-country financing;
- Multilateral counter-trade;
- Joint ventures; and
- Leasing.

5.6.3.2. Owner's equity

The ease with which the financing package may be arranged will depend on the level of financial resources that are available to the owner. The resources may take the form of owner's equity, subordinated loans or appropriation from the national budget. In general, the World Bank regards that as a rule the owner's equity should be in the range of 20–30% for the power sector. The International Finance Corporation (IFC), which belongs to the World Bank group as the private ownership institution of the International Monetary Fund, usually requires a minimum owner's equity of 30%. It should be noted that the amount of equity which the financial institutions require in a project is essentially a function of the debt service coverage ratio.

Another basic principle in financial planning is that local costs should be covered by domestic funds. Experience shows that raising enough money for local cost financing from foreign sources, local capital markets or government budgets has often proved to be difficult and has been the main reason for delays in project construction.

5.6.4. Negotiation and closure of a contract

5.6.4.1. General considerations

Selecting reliable contractors is probably the most important and most crucial decision in implementing a safe and economic NPP project. Case studies of NPP and other complex projects have shown that it is not only the provenness of a product and concept that counts, but also the provenness of the project set-up and of the organizations backing it. A newly formed consortium which has never executed a certain type of contract, domestically or for export, will have to undergo a learning process and may have start-up problems.

When preparing for contract closure, owner management in general and assigned project management in particular should ensure that the partners who are chosen completely cover the deliveries desired and the interfaces to adjacent scopes of supply and that one of them can accept a lead responsibility for the entire plant as part of one of the contracts (unless the owner can take on this responsibility itself).

It is important to check at this time that supplies of equipment and fuel, and their financing as well as any other long term items, have the backing of bilateral or multilateral government to government agreements. The reliability of a possible project partner (contractor) would in particular be evidenced by proper projections of costs and schedule and good prior performance on contract fulfilment.

The language to be used in the NPP documentation should be defined, including the identification of components and control room and field panels. Also emergency plans and public address annunciation should follow the same language.

5.6.4.2. Technology transfer and training

With regard to technology transfer and training for the first NPP, careful studies have to be performed to analyse the local capabilities in detail [14]. All information needed has to be collected by the bidders on a case by case basis, so that they can make a detailed proposal for a technology transfer programme and training package in their bids.

The analysis should identify the already existing capabilities in all areas connected with a NPP project. Furthermore, a plan for the future development of the local industry and infrastructures (including colleges, universities, etc.) should be elaborated, including budget planning. The results of such a study should be the basis of contract proposals for the first NPP project. The possibilities for the expected technology transfer programme and training package should be explained in the BIS.

A technology transfer and training programme, established mainly between the supplier's country and the buyer's country, comprises several steps. Technology transfer and training may be agreed among:

- Government organizations;
- Technical expert organizations;
- Research institutes (scientific cooperation in energy sectors);
- Universities and technical schools;
- Industries and utilities (NPP design and construction, component manufacturers, maintenance, operation);
- A/E firms.

5.6.5. Owner's management organization

The owner's management organization will represent the interests of the owner in the pre-contract, contracting and post-contract stages of project construction. The breakdown into these stages, of what is in fact a continuous activity, highlights the particular importance of the contract for this key organization.

5.6.5.1. General considerations

Before the start of plant construction activities, one or two professionals with project management experience should be assigned to the NPP project within the owner's organization or the appropriate national organization in charge. These professionals should preferably have a nuclear engineering background and/or obtain the necessary additional training. A project manager should be chosen and authorized to control all project matters and build up a multidisciplinary group of engineers to supervise the specification, design, manufacture, construction and commissioning of the plant. Figure 5 shows an example of owner's organization in a turnkey contract approach.

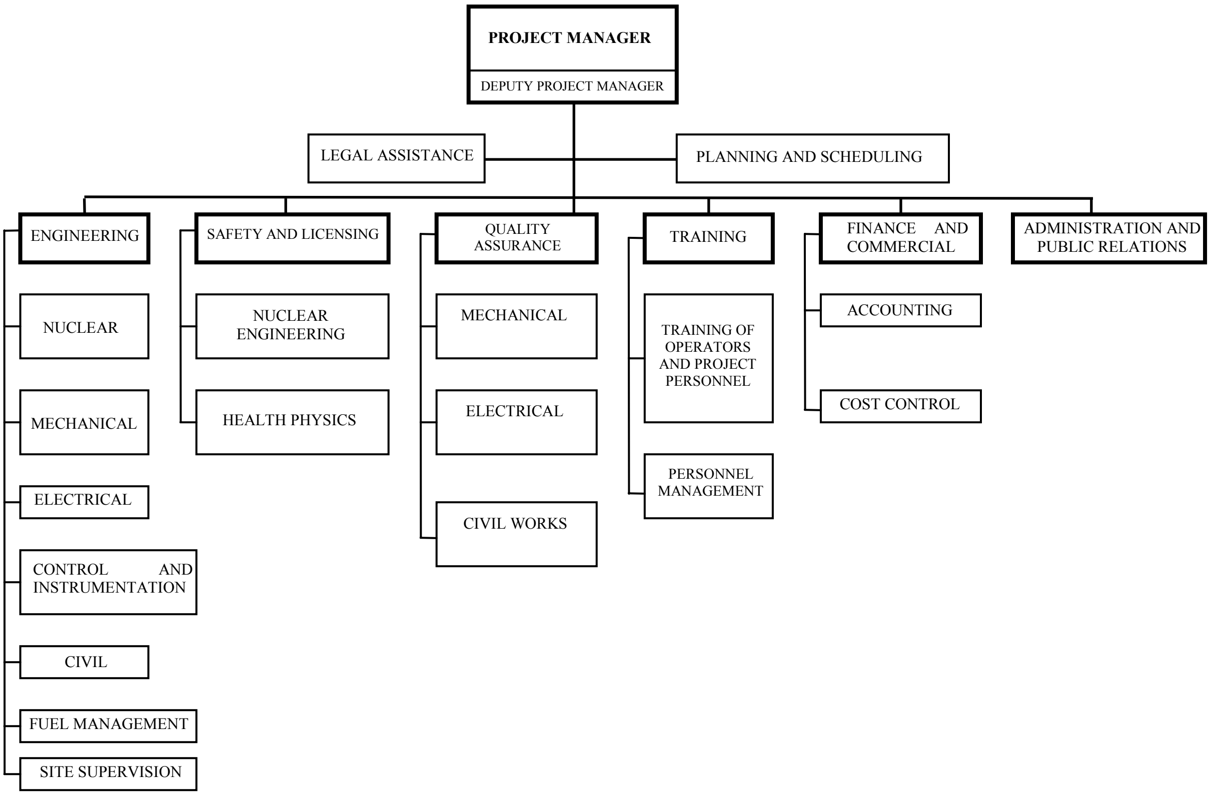

Fig. 5 Example of owner's organization in a turnkey contract approach (ref. [14]).

5.6.5.2. Pre-contract stage

During the pre-contract stage the project management team could work as a task force and serve as the project representation for the owner with at least one responsible and experienced professional for each of the following areas: systems analysis, radiation protection, reactor systems, auxiliary systems and secondary cycle, electrical systems, civil and structural, nuclear fuel, licensing, commercial and legal aspects.

5.6.5.3. Contracting stage

During contract negotiation the owner's management organization should grow to about 30 experienced people consisting of a core of the project manager assisted by a staff of 5 to 10 professionals and the beginning of an engineering department. This team has to handle all technical and commercial discussions which lead to the awarding of the contract(s) and then monitor its proper execution from the standpoint of the owner. The supporting engineering activity of the owner is seen as an integral part of the owner's management organization in terms of the distribution of responsibilities assumed here.

Note: Publications with additional information related to the issues covered in this chapter are listed in the Appendix III.

6. PLANT CONSTRUCTION STAGE

6.1. Project management

Project management is the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. Project management is accomplished through the use of processes such as: initiating, planning, executing, controlling, and closing. It requires highly qualified and experienced staff, because its role is decisive for the project's success. As in the previous project stages, all activities are accomplished fulfilling the established management system that ensures the achievement of all the NPP project goals, refs. [7, 9].

Project management activity starts with the definition of the project as a unique system to be produced with certain inputs, constraints and goals, ending with the turnover of the complete functioning system to another organizational entity, which will be in charge of operation and maintenance of the completed project.

The principal effort is usually with the main contractor or architect-engineer, but with independent overview by the utility's project management team. The project management and project engineering organizations will initially comprise some 20 to 30 professional engineers, but will eventually require 400 to 600 professionals, technicians and craftsmen.

6.1.1. Utility project management

For the purpose of this description of project management, it is assumed that the responsibility for design and construction is delegated to a main contractor, who therefore requires a large project management and project engineering effort. Should the utility choose not to delegate all or part of these responsibilities it will have to carry out these tasks and increase its staff accordingly. The utility project group will represent the interests of the utility through out the implementation stage.

A project manager should be chosen and authorized to control all project matters and build up a multidisciplinary group of engineers to supervise the specification, design, manufacture, construction and commissioning of the plant. These professionals should preferably have a nuclear engineering background and/or obtain the necessary additional training. The core of this project management group will have to contain about 15 to 20 highly qualified and experienced professionals. Details of the manpower requirements of the utility's project management activity and the technical qualifications necessary for such tasks will need to be established.

Different types of organizational structures can be adopted depending mainly on the utility's prevailing practice. In general, a matrix-type organization for project management seems to be advisable, mainly for multi-units project, because of the great complexity of a NPP project, where both specialized functional skills and overall coordination have to be combined to achieve the aim of getting the project done on schedule, within the budget and with the required quality [14]. The project manager in a matrix-type organization has the authority to tell all the members of the project team what to do and when, but not how to do it.

6.1.1.1. Main functions of the utility project management

The main functions of the utility project management throughout the plant construction stage are as follows:

- Preparing, reviewing and adapting the necessary project planning and implementation schedules;
- Preparing local infrastructure such as emergency preparedness including plan, hospital information centre, etc;
- Preparing a programme for public awareness on operation, incidents, accidents, radiation exposure, etc;
- Preparing the environmental base data;
- Steering overall requirements, monitoring progress and giving detailed approval of engineering;
- Assuring timely delivery of items in the utility's scope of supply;
- Ensuring the transport of equipment and the availability of site services;
- Carrying out expediting services;
- Maintaining effective project cost control;
- Certifying interim progress payments;
- Carrying out plant design reviews to ensure adherence to contractual conditions and regulatory requirements;
- Introducing and co-ordinating QA programmes/Management System;
- Reviewing QA procedures/Management System of contract(s);
- Ensuring control and proper construction supervision at the plant site;
- Supervising component manufacturing;
- Plant licensing: applications, revisions and negotiations;
- Interface with local authorities;
- Reviewing and approving plant safety and engineering procedures, as well as plant operation and maintenance manuals;
- Supervising plant commissioning and reviewing test results;
- Training operations' personnel;
- Giving final approval and authorizing payment of bills from suppliers;
- Preparing and issuing progress reports;
- Implementing plant security plan;
- Evaluating main contractor or subcontractors claims; and
- Maintaining contractual communications.

The monitoring of expenditures and maintenance of up to date budgets will be accompanied by technical supervision, such as approval of specifications, drawings and purchase orders, certification of work performed, inspections and QA, provisional and final acceptance, study of discrepancies and corrective action, and preparation of reports. Most important, however, are the management/interpretation of contracts, their definition, administration and enforcement.

6.1.1.2. Utility project management responsibilities in relation to software issues

The responsibilities undertaken by the utility project management in relation to software include:

- Supplying interfacing information and progress reports on work within the scope of the utility;

- Controlling the overall schedule and seeing that only one valid schedule is being used by all project partners;
- Evaluating alternative options originating from the main contractor during the early development of the engineering work, or assessing necessary changes;
- Approving the list of qualified subcontractors put forward by the main contractor;
- Checking the bids received within the scope of the utility;
- Reviewing and approving project requirements, analytical reports, drawings and technical specifications;
- Supervising the administration and execution of contracts delegated to the main contractor and/or architect-engineer;
- Verifying compliance of design and manufacture with the established project requirements;
- Closing subcontracts or contract amendments, as needed; and
- Fulfilling licensing requirements.

The utility in general and its project management in particular is responsible for the economic control of the project, including financial management, approval and payment of bills from contractors. In any type of contract the details of cost control, payments and/or financial resources should be clearly defined. Finally, the utility project management should be very much aware during planning and execution of the project of its future responsibility for the operation of the plant. This involves the proper preparation for operation and maintenance, the securing of appropriate documentation and the drawing up of plans for spare parts and fuel supply. Utility project management organization may include some procurement activities and commissioning activities and in some specific case, operation activities.

6.1.2. Main contractor project management

Similar to the conditions adopted in discussing the utility's project management, it is assumed for the purpose of this description that the responsibility for design, engineering, construction and commissioning of the NPP project is delegated to a main contractor. This would correspond to the case of a main contractor in a turnkey contract and also to the case of a non-turnkey contract where the utility delegates the above responsibilities to an architect-engineer who takes on the role of a main contractor. In any other case, the utility (with or without the assistance of consultants or an architect-engineer) retains the full responsibility for overall project management with all its functions and manpower requirements as described below.

A fairly equal ranking, co-operative but business-like relationship between the utility and the main contractor is highly desirable. The contacts between these organizations are the respective project managers, each one directing the project activities within his organization.

The project manager should be a professional with at least five years of prior NPP experience and demonstrated project management capability in another project team, not necessarily for a NPP. The project manager will normally start with a relatively small staff of 2 to 3 engineers to assist him (at least one with several years of experience in NPP projects), and should gradually build up his/her unit to full size by the time plant construction is initiated.

Project management is normally executed functionally (sometimes with the help of escalation-paths to upper management) within the framework of a matrix organization.

6.1.2.1. Main functions of project management (main contractor)

The main functions of project management (main contractor) are outlined as follows during the implementation stage:

- To define the project requirements resulting from contractual terms with the project partners;
- To establish a project breakdown for hardware and software and allocate the project budget through individual project task orders;
- To define, sequence, and initiate the project works in agreement with the sections and departments involved; to ensure the availability of funds and manpower;
- To deal with any problems which hinder the progress of the project or threaten its quality, to provide problem solving leadership and assistance where needed, and to establish a project risk analysis and risk reduction programme;
- To conduct separate regular meetings with project staff, line organization and project partners in order to monitor progress, take any necessary corrective action and communicate essential project information;
- To monitor expenses and project performance against budget and schedule, and to obtain proper authorization for major changes;
- To monitor the technical progress of the project in relation to the specifications and drawings (software) by ensuring compliance with project requirements;
- To co-ordinate the project activities and control project interfaces inside and outside the organization;
- To authorize specifications for manufacturing and installation of equipment;
- To set up purchasing procedures and controls;
- To expedite engineering and subcontractor deliveries;
- To ensure timely and proper preparation of licensing documentation and applications as well as adherence to compliance procedures;
- To monitor and control costs;
- To ensure progress payments and prepare claims for justified price changes;
- To help perform and establish the management system;
- To provide assistance, proper interfacing and transfer of information to the site management and the utility; and
- To report progress at regular intervals.

6.1.3. Project management rules and procedures

The project manager in each partner organization should be carefully selected. The hierarchical level at which the manager is to work should be compatible with that of section and department heads in charge of typical technical specialities in a NPP. In a team approach the project manager should be able to lead these technical managers and in the preferred matrix approach he should have the necessary authority to ensure his views predominate; his co-signature should be required on most project actions.

Since not all of the technical sections may have been involved in the pre-contract and contract stages and some of them could be working on other projects, a written instruction from the organization’s highest management level is a first practical step to get project work started in a properly authorized manner. Such an announcement should immediately follow contract signing. It should serve to present the project manager, state is level of authority and responsibilities within the organization, provide basic information on the type of project organization chosen, establish budget codes, and clarify preliminary communications and signature procedures.

The implementation and control of project definition and the communication of decisions are continuous tasks during project execution, but are particularly important at the beginning. As far as possible, front-end definition should be achieved, even if corrections have to be made later. The interpretation of contractual terms into concrete project requirements usually involves a special effort by project management. Whatever is decided and detailed in a permanently valid form for the project organization should be established in writing and collected in an appropriate form, i.e. in manuals. The object of a project manual within any partner organization is to make readily available the rules governing the relations and task distributions between the various participating departments and with other project partners. The characteristics of such a project manual can be outlined as follows:

- The rules described in the procedures should be compulsory for all the organizational entities over which the management of the partner has disciplinary authority;
- The project manual should observe the hierarchy of project contracts and partners, i.e. make clear who is holding what type of funding and approval authority in which type of contract. The utility's manual may serve as a general guide and may be used by the architect-engineer, main contractor or consultants, as needed;
- The manual must include a procedure to be followed for its own modification and updating;
- The manual will refer only to the principal relations with other project partners, in particular communications and approval channels, without including in detail their individual internal organization; and
- The contents of the manual must be discussed with the main project partners involved, at least between utility and main contractor or utility and architect-engineer and contractors.

Just as there is an organizational hierarchy for the project management of the project partners, there is a hierarchy in documents (such as procedures and manuals) for project direction. While the utility would have the lead in compiling the general portions of the project manual, other partners would add details and their own internal procedures. If one of the project partners is a consortium, there would most likely be a further hierarchy of project management and of manuals from the consortium level to that of individual organizations.

There is also a need for manuals which delineate internal procedures in each of the project partner organizations (which could have more a line management character) and would apply to a product line and/or to several different projects. It is a recommended practice for NPP project management to prepare a single document for any particular project, in which the project specifics are outlined and proper reference is made to other more general procedures of the organization.

Where in some particular case or for some purposes the standard procedures are not applicable to the project, specific procedures have to be prepared. These will be written following the directions or specification of the project manager and are sometimes referred to as a project organization manual.

The project manual may also be in the form of a set of manuals, for example:

- Project reference information;
- Project procedures manual;
- Internal procedures and guides; and
- Codes, standards and regulatory requirements.

The parts of manuals applicable to the management system must have the approval of the appropriate units within the partner organization. The project manual (or portions thereof) is sometimes a part of the management system of the organization. In these cases a controlled distribution must be made and change control and enforcement of the manual will have to comply with the established procedure.

The documentation of communications, planning and control procedures may generate a large amount of paper. Once project procedures have been established and made known (i.e. via a manual), associated forms and reports can be developed, listed in the manual and distributed. Administrative or organizational specialists in the partner organization may help project management to develop these documents. The project manager must be careful to watch the time he spends on this type of activity and should ensure that not too much bureaucracy is introduced.

6.2. Project engineering

The starting point for the conceptual design is the NPP capacity and the physical features of the selected plant site. It is generally the owner's responsibility to perform, perhaps with the assistance of consultants, all the necessary field investigations needed to obtain the site parameters which can have an influence on plant design. Thus, complete information on the hydrology, meteorology, topography, demography, geology, seismology, etc. of the plant site has to be obtained (information obtained during decision-making stage); this information will also influence the preparation of the preliminary safety analysis report.

Project engineering work requires some three million (3,000,000) man-hours of effort over a relatively short period (three to five years). This can either be done by the utility itself or by its architect-engineer or main contractor or by a combination of efforts from some of the participants. But even if the more usual (architect engineer or main contractor) approach is adopted, the minimum involvement of the utility (review and approval) will amount to about 50 000 engineering man-hours.

With the venue of Advanced Reactor Construction Technologies and Schedules (36 to 48 months construction time from first concrete to fuel load), the approach to project engineering has changed somewhat with the need to have the design complete at 90% or greater and all identifiable engineering and licensing issues resolved before construction starts. This constraint will likely be the single biggest factor in controlling the construction schedule. In addition, the need for modularization to support these short construction durations has brought forward some non-negligible constraints and several unique problems to project engineering.

6.2.1. Project engineering main tasks

Project engineering involves the following main tasks:

- Basic design criteria definition, including the definition of applicable standards and regulations;
- General plant layout;
- Project scheduling;
- Design of plant systems, including seismic and stress analysis of plant components;
- Preparation of Systems’ Design Manual;
- Transient calculations and accident analysis;
- Piping and mechanical design and drawings;
- Civil works, electrical, control and instrumentation design and drawings;
- Operational Radiological Exposure (ORE) optimisation;
- Preparation of equipment specifications;
- Preparation of preliminary and final safety analysis report;
- Procedures development;
- Participate in start-up, and commissioning tests;
- Participate in the preparation of operations manuals;
- Support procurement and licensing activities; and
- Implementation of a management system.

Successively and according to the project schedule, building drawings and equipment specifications are produced through the detailed engineering effort. These will be used as procurement documents. Ultimately they will be used by constructors and by equipment manufacturers as well as by the commissioning staff. The equipment and component procurement activity is often a centralized service requiring a staff of 30 to 40 professionals and technicians.

Another output of the project engineering effort is the reporting of plant design and performance in licensing documents. The exact format and volume will vary from country to country; however, in general, the nature and depth of the required safety information is similar. Generally, also, a preliminary safety analysis report (PSAR) is required in support of the application for a construction permit, and a final safety analysis report (FSAR) must be submitted in order to obtain an operating licence. Some countries (including most financial institutions) also require an environmental report (ER) wherein the potential impact on the environment of the NPP construction and operation is assessed.

6.2.2. Scope of engineering

Engineering of a NPP starts with the controlled ordering or authorization (through project management, within budgetary and schedule constraints) of a design or analysis activity and ends with the issuance of drawings, specifications and analysis reports and support of procurement activities, which allow the production and installation of hardware and ultimately plant operation.

Regardless of the type of organization which may exist in a given country for the NPP plant construction, project engineering constitutes a challenge in manpower development, requiring as it does large numbers of highly qualified personnel. It is a key activity in plant construction, which interrelates with all other project activities.

Engineering of a NPP of a proven concept (i.e. not first of a kind) involves up to three million man-hours accounting for about 10% of total plant costs. Incorrect, insufficient or untimely engineering means schedule delays and cost-overruns and can affect plant safety, reliability and availability.

6.2.3. Organization and manpower needs for project engineering

The engineering effort related to NPP projects is in general performed by a separate department or organizational unit, because of the specialization and unique requirements of such projects. An engineering department is usually self-sufficient and may perform, in addition to the actual 'project engineering' work, central services such as scheduling, procurement, personnel management and administration. Owing to similar product sub-divisions, the hardware and software specializations lead to a similar structuring of engineering disciplines in companies around the world. Minor variations primarily exist because of different philosophies in combining or dividing work on specializations such as core design and fuel engineering, safety analysis and licensing, component design and related analysis, etc.

Experience has shown that the interrelationship of different engineering disciplines and of engineering with project management has worked out best with a matrix-type organization for multi-projects station. Since no one can maintain proficiency in all disciplines simultaneously, an authoritative chain-of-command approach is ineffective and dangerous in this activity. An environment has to be created where lead engineers can speak up to represent their disciplines. This inevitably leads to a certain amount of management by committees and sometimes to confusion. Proven ingredients for successful engineering management are:

- Knowledgeable and co-operative persons in key positions;
- Concurrence of project management and project engineering in major decisions; and
- Early documentation and written approval of decisions in the form of engineering documents and specifications and firm control over any changes or deviations from them.

The engineering organization provides typically services in the form of preliminary and conceptual designs, licensing documentation, basic and detailed design, equipment specifications, procurement support, manufacturing surveillance, modifications, erection and commissioning support and as-built documentation.

A utility may choose (if it has adequate capability) to perform project engineering within its own organization, with or without the assistance of an architect-engineering firm or consultants. It may also choose to delegate this responsibility to a main contractor with adequate experience and capability, while maintaining a supervisory function carried out by the utility's project management team. There is also the possibility of retaining some project engineering functions and delegating others. For the purpose of this description the delegation of the project engineering activity to a main contractor is assumed. But, whatever approach is adopted, the overall project engineering effort and the corresponding manpower requirements are similar. At the peak period for the engineering of a single unit plant about 300 to 400 professionals and technicians are typically required, but this number might be substantially larger (even double) or somewhat smaller, depending on the scope of the engineering effort, prior experience of the organization and standardization of designs.

A typical manpower loading curve shows that about 5% of the engineering peak staff is required during the early period of the plant construction. After a letter of intent is issued, the staff would quickly build up to meet the project objectives. By the start of construction, it will have already achieved or be close to its peak, where it would remain for one to two years and then gradually decrease.

Project engineering is a project-oriented activity; however, building up and staffing a NPP project engineering organization would hardly be justifiable and difficult, due to lack of continuity, for a single project. Assuming a sequence of NPP projects, project engineering would become a continuing activity and the overall manpower requirements would depend on the number of projects to be engineered simultaneously.

6.2.4. Plant design

At the outset of project activities, the utility project group has the lead role in defining, possibly with the help of consultants, the NPP project in terms of plant size, site conditions and bid specifications. If the project engineering is to be delegated, the major portion of the engineering effort is gradually taken over and performed by the main contractors who will create their own project group. If more than one organization is selected to produce the engineering of the plant, coordination between these should be a real concern right from the start.

6.2.4.1. Plant conceptual design

The conceptual design task involves the following main activities:

- Defining the site conditions for consideration in plant design;
- Establishment of required plant elevation making provisions for protection against floods or tidal waves, if necessary. Making general arrangements of plant layout and for intake and discharge channels for cooling requirements;
- Defining design conditions with respect to safety standards, seismic analysis and security, etc.;
- Determining the approximate size of the main and auxiliary buildings and the preliminary layout with due consideration to space requirements for component delivery, erection and maintenance;
- Preliminary design of site access during construction and subsequent operation of the plant. Preliminary design of harbour and docking facilities or definition of utilization schemes of existing ones (if relevant);
- Identification of hot areas, clean areas and other critical areas. Preliminary design of access and working areas, with due consideration for worker safety and radiological protection;
- Determination of preliminary layout of indoor high-level radiation equipment so that maintenance work can be done with minimum radiation exposure of workers;
- Preliminary design of protection devices and escape routes (shielding structures, partitions, isolation devices for radiation accidents, fire or other abnormal conditions); and
- Determination of water and power requirements during construction, commissioning and operation.

For the first NPP in a country, or a first unit at an unusual site, the conceptual design task can involve between 20 to 30 experienced engineers and technicians for a period of up to two and a half years (for subsequent units or uncomplicated sites, one to one and a half years should be adequate). It is a task that should normally be completed about seven years before commercial operation of the plant.

At the end of the conceptual design task all major characteristics of the plant should be defined and all questions with regard to the pre-investment and requirements (regulatory body and utility) of the plant and the site should have been answered. The results take the form of systems descriptions, conceptual drawings, data compilation and preliminary licensing information. These results should be subjected to an independent review by experienced engineers who are senior professionals not previously involved in the conceptual design development. Consultants who have previous experience on other similar projects may also be utilized. For the required review, a total effort of at least 2,000 man-hours would normally be required.

6.2.4.2. Basic and detailed design engineering

The next task of design engineering can be divided into two according to the degree of sophistication of the task, namely basic and detailed design. Basic design engineering can involve 300 000 to 500 000 man-hours for a period of 6 to 12 months and a staff of around 200 to 300 people. A high level of engineering practice is required for this part of the design. It involves the following main tasks:

- Basic design criteria definition;
- Preliminary engineering programme development;
- Definition of applicable codes, standards and regulations (local and foreign);
- Definition of applicable engineering procedures;
- Preparation of Systems Design Manual;
- Preparation of equipment specifications;
- Preliminary safety analysis report preparation;
- General plant layout preparation;
- Preliminary piping and instrumentation diagrams development; and
- Quality assurance programme/Management System preparation.

In the basic design the safety criteria needed to meet the licensing requirements set by the national regulatory body are defined. Also the reference plant for the project, if any, has to be defined.

The task of detailed design engineering involves about 2,500,000 man-hours of effort during a period of some three to five years.

To entertain the objectives of the venue of the Advanced Reactor Construction Technologies and Schedules (36 to 48 months construction time from first concrete to fuel load), this engineering effort will require some major adjustments to the decision-making and to the plant construction stages.

Involvement of practically the entire engineering organization is generally needed for the activities beyond the conceptual design task. In particular, with respect to the three main parts of the plant - nuclear steam supply system (NSSS), turbo-generator (TG) and balance of plant (BOP) - design engineering takes into account the following aspects:

- NSSS and TG. These parts of the plant are generally of manufacturer's standard design. There may be a need for some modifications resulting from the site conditions that will affect condenser size and tube material, turbine design, etc. as well as from the owner's requirements. If the local industry is to supply some equipment for these parts of the plant, a greater amount of effort in the detailed design will be needed to make this equipment compatible with the manufacturer's standard design;
- BOP. This part of the project will involve special detailed design effort because of the large influence of site conditions and relatively more national participation to be expected.

There can be substantial national participation in detailed engineering even for a first NPP project from engineering firms with experience in large industrial projects (petrochemical industries, power plants, etc.) and, in particular, in areas of building and system design with a low degree of nuclear specialization. The main jobs involved relate to:

- Detailed project planning and programming;
- Calculation and design of plant systems;
- Seismic analysis;
- Stress analysis for plant components;
- Piping design;
- Transient calculations and accident analysis;
- Plant specification;
- Specification of equipment and components;
- Detailed plant drawings;
- Commissioning tests manual preparation;
- Operation, maintenance and emergency manuals preparation;
- Final safety analysis report preparation;
- Procurement support; and
- Configuration management.

In the performance of the above jobs, the engineering organization must ensure that the design conforms to codes, regulations and standards as specified. The detailed design should be continuously reviewed to verify that safety criteria, the security requirements and other relevant technical requirements are satisfied. In particular, design guides for piping, valves, storage tanks, cables, control panels, limits of allowable vibrations, temperature rise in bearings of rotating machines, etc. have to be in compliance with established standards.

Detailed design must also consider plant equipment reliability and operability. Ease of access for maintenance and inspection of equipment should receive careful attention. Adequate space and sufficient hoisting capacities have to be verified. Adequate provisions for spare parts of equipment essential to operation must be assured.

The preparation and review of equipment and component specifications constitute an important part of the detailed engineering task. The result of the design work will ultimately be passed on to sub-contractors in the form of equipment and plant specifications and drawings. The production of these documents is a major effort involving not only the design engineers but also other technical personnel knowledgeable in the areas of manufacturing, materials, engineering, licensing and quality assurance. For specifications work, in particular, there should be at least 10 to 12 engineers with prior (not all nuclear) specification writing experience to lead the task of specifications development, including such activities as:

- Production;
- Internal review;
- Editing;
- Approval by utility;
- Compliance with regulatory requirements;
- Dealing with sub-contractors;
- Manufacturing;
- Quality assurance/Management System requirements;
- Revisions and updates; and
- Final filing and retrieval.

The above level of effort assumes that maximum use is made of common and generic equipment specifications and that substantial portion of these specifications are produced by the sub-contractors who will manufacture the equipment.

6.2.5. Utility's role in project engineering

In general, the primary objective of an electric utility is the supply of electricity to the public. It might also perform project engineering for its own power plants, but this would not be the usual case for NPPs. From the national participation point of view, in the absence of local NPP project engineering capability, as large an involvement of the utility as possible would be preferable, but a realistic assessment of the utility's available qualified manpower and expertise may dictate different arrangements which limit its role. But whatever the contractual arrangements may be, the owner of the plant must bear the overall responsibility for the plant and, in particular, the responsibilities for all actions which are relevant to ensuring plant safety and security.

Adequate staffing with qualified personnel is the first and most important task the utility/owner has to face. The type of contract would define the engineering tasks and functions to be performed by the utility's personnel. This would mainly affect the quantity of qualified personnel required but not their qualifications, which should be at the same level of expertise as those of the main contractor's engineering staff.

The utility/owner must also enforce surveillance and control that the project develops in close conformity with and strict adherence to the established safety standards. The utility/owner will have to demonstrate to the regulatory body that the plant meet all the licensing requirements and that it is capable of operating the plant in a safe and reliable manner. During engineering review the utility/owner will therefore verify not only that the supply is within the established scope but also in strict conformity to the design assumed as reference for licensing compliance. The utility should initiate frequent or regular meetings with the regulatory body to address sensitive safety matters as early as possible. It is highly recommended that the vendor attend these meetings considering the potential impact of safety on the design.

Effective and efficient practices for QA must be enforced and/or supported by the utility's engineering group and carefully and consistently executed at every stage of development of the project. Auditing techniques must be devised whenever necessary during manufacturing of components.

The utility's manpower requirements associated with this activity will of course depend on whether it wants to perform some complete QA functions itself or-retain only minimum QA functions with four to five professionals, delegating implementation to others.

The utility/owner could take responsibility for the design of certain parts of the plant which are of a conventional nature and for which previous experience exists in its (possibly fossil power plant) engineering groups. For instance, a great deal of work in the areas of building design and civil engineering, auxiliary systems and facility design and transmission system design could be performed by the utility/owner's personnel.

As for specification reviews and approvals, the utility should make available two to three engineers who should seek advice from the rest of the utility staff as needed. Regulatory efforts in licensing and compliance would also require the utility/owner's participation and involve about four to six professionals. For the utility/owner's minimal participation in the tasks described in this section, the project engineering manpower effort will amount to about 50 000 man-hours during the basic and detailed engineering activities of the project, which means a staff of about 25 professionals. This is part of what has been defined as the utility project management effort.

6.3. Licensing, safeguards and physical protection

6.3.1. Provision of resources for licensing

To perform the licensing application activities, a small team of four to six professionals is usually required. Most tasks need not only technical but also legal and administrative expertise, in view of the interfaces among several organizations. Whenever export licences are required, there might be an additional task of satisfying some regulatory requirements of the exporting country.

The utility's licensing application group should develop close contact with the regulatory body as early in the project as possible, to understand fully the requirements of the regulations and to avoid problems of misinterpretation later on. In certain countries, it is not unusual that a Safety Option Report (SOR) is transmitted to the regulatory body, even before the plant construction stage. The evaluation of the SOR by the regulatory body results in recommendations and expectations from the regulatory body and commitments of the utility, to be addressed in the PSAR. This anticipated process might help include additional requirements in the BIS and prevent contract modification with the vendor.

Since the licensing process is a continuing one which does not end even with the granting of the full operating licence, it is important that an appropriate documentation system be established to keep a record of licensing issues and their status, especially those that are pending resolution. This is why configuration management is essential [16].

Configuration management is the process of identifying and documenting the characteristics of a facility's structures, systems and components of a facility, and of ensuring that changes to these characteristics are properly developed, assessed, approved, issued, implemented, verified, recorded and incorporated into the facility documentation.

An improperly organized licensing documentation system has been known to cause delays in the issuance of construction or operation permits and thus in the entire project. Constant dialogue and communication should be maintained to ensure that the project schedule will not be delayed.

Changes in regulations and standards, which occur as a result of operating experience analysis and additional research, also have to be monitored by the licensing application group. The cost of a late change in a regulatory requirement (which may mean back fitting) depends strongly on the time of introduction into the project schedule, i.e. the licensing group should judge the potential effects of such changes and alert project management to them. Furthermore, the group should strive to improve nuclear safety by improving the licensing procedure - through suggestions, review of drafts and, in general, through co-operating with the regulatory body.

6.3.2. Safety analysis report

In support of its application for a construction permit for a NPP, a utility is required to submit a safety analysis report to inform the regulatory body of the detailed nature of the plant and its intended use. The objectives of the report are:

- To provide a clear identification of the safety-related design basis for the plant;
- To provide a sufficiently detailed description of the system; and
- To demonstrate compliance of the design of the plant at the particular site with the stated design basis.

Most of the work is usually performed in project engineering. The following major disciplines have to be covered:

- Safety of the project site, including the site’s physical characteristics, and the population density and land use of the site’s surroundings;
- Design of the reactor and essential systems, including the principal design criteria, the design and operating characteristics, unusual or novel design features and principal safety features;
- Analysis of performance of structures, systems and components of the reactor to allow assessment of the risk to public health, to the environment, to properties and safety resulting from normal and abnormal plant operation;
- Organization and conduct of operations personnel training, retraining and qualification;
- Quality assurance programme/Management System to be applied during the design, manufacturing, construction and testing of structures, systems and components;
- Design of the reactor and essential systems, including the principal design criteria, the design and operating characteristics, unusual or novel design features and principal safety features;
- Assessment and implementation of ALARA programme; and
- Analysis of performance of structures, systems and components of the reactor to allow assessment of the risk to public health and safety resulting from normal and abnormal plant operation.

Within the utility undertaking the NPP project, application for licensing is usually one of the tasks of Project Management. Activities concerning licensing start early in the decision-making stage, when the regulatory body is contacted about siting considerations. A licensing specialist should already be assigned at that time to the team.

Licence application activities proceed during the decision-making stage all through plant construction stage and culminate with the obtaining of the operating authorization from the regulatory body. Various compliance efforts continue thereafter throughout the entire operations stage.

6.3.3. Provision of resources for safeguards and physical protection

While it is not possible to define the number of staff needed to administer a ‘State System of Accounting for and Control of Nuclear Materials’ (SSAC) under all circumstances, as an approximation one can envisage the establishment of one or two professional posts at the national level to operate such a system. One professional will be needed to operate the system at the plant and a full or part-time professional at the national headquarters for co-ordinating the system and for the data translation needed for the State/IAEA interface. The professional staff would require clerical and secretarial support to the extent needed to operate the State System as designed.

The concept of physical protection is one which requires a mixture of hardware (i.e. security devices), procedures (including the organization and training of the security force for the performance of their duties) and facility design. The IAEA has published INFCIRC/225 which contains recommendations for minimum levels of physical protection for NPPs. A number of countries have adopted these recommendations.

Adequate physical protection of the plant and of any nuclear material is fundamentally a national responsibility. The activity requires mainly administrative and security functions, with a staff of 20 to 50 people, depending on local conditions.

6.4. Procurement and expediting of equipment and materials

With a turnkey arrangement the main contractor has the responsibility for procurement of every item of equipment and of materials within his scope of supply, which could be the entire project. With non-turnkey arrangements the responsibility for procurement is either with the utility/owner, or can be shared among the utility, architect-engineer and system suppliers or contractors, each within its specific scope of supply.

Procurement of equipment for a specific plant is project-oriented, in that it involves every item for the entire NPP. But, of course, with several projects going on, the procurement activity acquires a continuing character and hence requires a permanent organizational unit with the corresponding staff.

Procurement starts with the establishment of the need for equipment orders as dictated by the project schedule and the existence of equipment designs and specifications. It ends with the verification of the fulfilment of the supply contracts, which can last through the commissioning stage of the plant. The activity itself then continues throughout the operation of the plant; during this stage it consists of procuring replacement parts, spares, and consumables. Procurement of fuel and fuel cycle services is usually treated as a separate activity, but it could be part of the tasks to be performed by the procurement unit.

The procurement activity has two principal aspects. One of them consists of the specific technical aspects, which are due to the nature of the items to be supplied; the other consists of the commercial and legal aspects, which depend on the applicable practices, rules, regulations and laws. Procurement, besides having an important influence on the financial and economic aspects of a project, also affects the project schedule as well as the reliability, availability and safety of the plant. A specialized procurement unit consisting of both business and engineering talent is therefore usually entrusted with:

- Establishment of procurement criteria;
- Procurement planning;
- Supplier qualification and selection;
- Bidding and bid evaluation;
- Contracting;
- Contract monitoring and enforcement;
- Expediting; and
- Handling of warranty claims.

Through its activities, the procurement unit can become the prime tool for the promotion of national participation and the controlled stepwise involvement of qualified local industries. It could, in some cases, act as an intermediary between industries at the threshold of a manufacturing capability and project management and project engineering which might be reluctant to switch from an experienced foreign manufacturer.

If procurement is performed by a centralized independent unit, this would require working with and for project management and engineering within the framework of a matrix organization. Some organizations choose a reporting relationship to project management either directly or by delegating purchasing experts to the project group.

Procurement could also be handled directly by project management or by project engineering. The manpower requirements and qualifications correspond to a centralized independent procurement unit and to the procurement of practically all plant items by this unit. A staff of about 25 to 40 professionals and technicians would be required. The organizational structure as well as manpower requirements would have to be adjusted to the scope of responsibilities and supply which procurement has to handle.

6.5. Manufacturing of equipment and components

6.5.1. Manufacturing main tasks

Based on the specifications produced by project engineering, equipment will be manufactured and delivered to the site as finished and approved products ready for installation. This activity requires mostly technicians and craftsmen of many different skills and qualification levels. It also requires adequate industrial infrastructure and technology.

Equipment and components represent the largest direct cost item for a NPP project. The construction of a 1000 MW (e) plant involves the casting of approximately 300 000 m^3 of concrete and the manufacturing of thousands of tonnes of steel, some of it of special grade. It will require about 30 000 separate items consisting of millions of parts requiring different levels of skills and quality for their production and installation. Some equipment manufacturing has to be started as early as two to three years before the first structural concrete is cast, the last pieces being delivered and installed during commissioning of the plant.

Equipment manufacturing is the largest block of man-hours in a nuclear project, approximately 20 million man-hours for a 1000 MW(e) plant. This number can vary considerably from country to country and also depends on differences in product sub-division and accounting methods. Labour required for the manufacture of ingots, sheets, forgings, etc. or mining labour for raw materials is usually considered as part of the material costs, thus leading to an underestimate of the manpower involved. A typical cost breakdown for mechanical and electrical equipment would be 50% for direct and indirect man-hours for foremen, craftsmen, labour and administration; 10 to 15% for equipment engineering and production engineering, 20 to 25% for materials, 10 to 20% for financing, plant amortization, and general overheads.

Equipment and components are divided into several safety classes according to the influence that their failure could have on the safety of the plant. All the NSSS equipment and components and a large portion of the rest are included in Class 1 (highest requirements). The quality requirements for this equipment are very high and a strict QA programme has to be applied to them. Conventional equipment not related to the safety of the plant does not need to fulfil the same strict quality requirements, although higher standards than those normal in conventional fabrication are needed to ensure a high reliability and availability of the NPP.

In countries with limited resources of highly skilled manpower, national participation would logically start with equipment of the lower degrees of nuclear specialization or of a lower safety class. Utilization of manpower which has had experience in existing conventional industries depends on the industrial infrastructure and is most easily done for equipment in the lower safety classes.

6.5.2. Equipment manufacturing organization

A typical equipment manufacturing organization normally consists of the following main divisions:

- Design;
- Planning;
- Production;
- Quality assurance/Management System;
- Inspection and control; and
- Erection.

In addition, there would be divisions for procurement and storage, maintenance, R&D as well as other supporting services.

The overall manpower requirements for the manufacture of equipment and components (excluding erection) are estimated to be of the order of 3000 professionals, technicians and craftsmen (unskilled workers are not included), for a NPP.

These overall numbers must be interpreted very carefully. Several hundred industrial manufacturing plants might be involved and their product lines would not be for nuclear equipment alone. In fact, for most of these industrial facilities, the manufacture of NPP equipment and components may represent only a relatively small portion of their overall output. Consequently, the overall manpower employed by these industries would be much larger than the number quoted above and many of these people would be directly or indirectly involved. For manufacturing all the equipment and components of a NPP, a high level of development of the industrial infrastructure is necessary, with all its experience, technology, know-how and qualified manpower.

6.6. Plant construction, erection and installation

The construction, erection and installation of plant buildings will require one or more qualified civil engineering and construction firms. The work will require at least 2000 skilled and experienced workers on the site at the peak of the construction period. It will require a strong and experienced site manager and an effective site organization, which is essential for the success of construction work. A substantial preparation for the site work and infrastructure on the site are required (job site offices and workshops, temporary and definitive roads, concrete preparation plant, temporary job site electrical net, illumination, water/air compressed net, sanitation, fire fighting net, etc) even before the first structural concrete (usually defined as the base-mat of the reactor building) is cast. The component and equipment installation should be performed by well trained technicians and craftsmen, under the supervision of experienced professionals.

6.6.1. Site construction

Site construction begins with preparatory work three to six years before fuel load, which marks the near end of the construction stage. Often, this work will start even while contract negotiation is on-going and at the time where a Letter of Intent is emitted to the potential vendor. The role of the utility/owner will continue throughout the construction through its project management tasks which will become more intensified. Project management will now include a team of construction experts at the site who will supervise and control the construction of the plant. A minimum of five professionals of the utility project management staff should be stationed at the site for this purpose.

A more important utility on-site staff build-up will commence with the preparatory activities for plant commissioning and operation and maintenance. The activities of the main contractor(s) and sub-contractors during this stage of the project will determine the needed manpower requirements and qualifications. Local conditions and site characteristics will have a strong influence on these requirements.

6.6.2. Site organization and management

Nuclear power plants are normally located in areas of low population density. Thus, the plant site will be at some distance from the contractors’ or utility’s headquarters offices, which are normally located in an industrial centre. The site management responsibility is different from overall project management responsibility; the latter includes planning, engineering and procurement. Thus, a proven arrangement, which is usually used, is to have a site management unit under headquarters’ control, closely co-operating in a defined way with the overall project manager and having the following responsibilities:

- Perform the project management tasks which are applicable to the specific site activities;
- Provide an effective organizational infrastructure to support the management and supervision of tasks;
- Co-ordinate all site scheduling information in order to minimize construction time and costs, while optimizing the utilization of construction personnel;
- Provide technical interpretation of engineering and design information;

- Establish warehousing, cost and material control procedures at the site; and
- Set up formal and informal communication channels with sub-contractor personnel at the site and at headquarters.

Since the prime task on the site is project execution as defined by headquarters, a simple line organization (non-matrix) with a strong chain-of-command is most effective. The site manager should have proven authority and management capability, preferably acquired at the site of another NPP or at another large project (e.g. fossil plant, refinery, etc.). Varying degrees of headquarters support are needed throughout this stage of the project. Usually a site-engineering or field-engineering group will be needed, which normally reports to the headquarters project-engineering division. Its objective is to approve or take other action with regard to the changes to design specifications, suggest/approve on-site modifications wherever required, and ensure that the design intent is met during construction.

While site management has its own planning and scheduling unit which schedules and controls all its activities, it is necessary to have very close coordination with headquarters project management to ensure achieving the overall project objective. This site scheduling unit can be supported by the headquarters' organization for any computer services, if such services are not available on site. Sub-contractors for one or more construction lots typically have management and engineering support on the site amounting to about 8 to 10% of the workforce. The proportion is on the higher side at the beginning and becomes lower during workforce peaking.

If responsibility has been delegated to a main contractor, experience has shown that the utility site organization should be structured along similar lines as that of the main contractor and should maintain close liaison with it. The main function of this utility site organization is to supervise, control and inspect all stages of the construction work; but on-the-job training of personnel for future projects may also be an important aspect. If the utility retains the overall project management task, its site management staff will be somewhat larger than outlined for the main contractor, because it must carry out the responsibilities of both the owner and the constructor.

The construction stage of a NPP includes a multitude of activities affecting quality which are performed by various organizations with specific responsibilities assigned to them. These include building, manufacturing, erecting, installing, handling, shipping, storing, cleaning, inspecting, testing, modifying, repairing and maintaining. Each of the participating organizations is responsible for the establishment and implementation of a QA programme to be accepted and supervised by the utility/owner and commensurate with the construction activities being performed and their importance to plant safety.

Site administration for locations far from industrial population centres, with difficult access, or in foreign countries may require up to 100 people for special efforts in:

- Organization and control of transport, expediting, customs, relation with port authorities;
- Organization and management of infrastructure for expatriates and local staff, such as housing, provisions, catering, medical services, recreation, security; and
- Personnel transport, general services.

6.6.3. *Site preparation*

As a part of the siting study for the NPP project the size of the land area, access routes, foundation, ground water and geological characteristics are evaluated. This task is usually done under the lead of the utility pre-project team with the assistance of consultants as needed, sometimes already involving the main contractor, should there be one. Once the distribution of project responsibilities is established and the site information from the pre-project stage is evaluated, the following site preparation activities are undertaken:

- Building or upgrading access roads and bridges to a heavy duty status. Where possible, rail connections and access to navigable waters and prior docking facilities should be made available to handle heavy components in the most economical way;
- Provision of flat, suitably graded, crushed stone surfaced lay-down storage space for open storage of materials and equipment. This location should be properly fenced and provided with security services;
- Construction of temporary warehouses for protection of equipment. Portions of these buildings should be provided with environmental controls;
- Installation of site and area fencing for security purposes during construction;
- Installation of communications systems to the outside and within the site;
- Installation of fire protection equipment and facilities;
- Site levelling, where necessary, and flood protection of the site;
- Provision of adequate electric power, fresh water and compressed air supplies for the construction period;
- Allotment of temporary construction office buildings and housing for construction personnel; and
- Provision of auxiliary services and facilities such as first aid, hospital, canteen, parking, etc.

Part of the site infrastructure would consist of small to medium size workshops which would be required to take care of some on-site-fabrication works, fabrication of some embedded parts and structural items. Although such items can be manufactured by contracting them out, field workshops are essential to take care of urgent requirements so that construction work is not held up. If such facilities are not set up at the earliest stage of construction, the project will eventually be negatively affected by not having them.

Depending on the difficulties of the particular site, the tasks to be performed will require normally 50 to 150 craftsmen and labourers during this stage as well as 10 to 20 professionals and managers, who have previously performed similar duties. The number of craftsmen and labourers could increase by as much as a factor of five for exceptionally difficult sites, taking into account that the above tasks should be completed as quickly as possible.

6.6.4. *Erection of plant buildings and structures*

With the casting of the first structural concrete (above the water-proofing and special foundations) the erection stage has begun. This activity, often referred to as the casting of the 'base-mat', is a major milestone in the project schedule. For this and the subsequent building work the following requirements and activities are essential:

- Prior selection of experienced concrete manufacturers, and installation of cranes and modern concrete-making equipment;

- Timely installation of underground supply systems for site work and for the power plant, with proper consideration given to the transport of heavy loads during construction;
- Prior ordering and delivery of nuclear-grade rebar, and establishment of qualified rebar preparation and lacing faculties at the site;
- Establishment and enforcement of the necessary QA and inspection procedures for concrete;
- Assurance that construction drawings are correct and up-to-date and that they are properly interpreted and implemented by construction personnel;
- Timely delivery, site manufacture and QA of steel parts (such as anchor plates) to be cast into concrete; assurance of proper markings and correct placement with the help of clearly marked construction drawings;
- Proper sequencing and monitoring of construction progress for different building portions with the assistance of the contractor's civil engineers and of independent civil and structural inspectors; consideration of building interfaces; planning and provision for temporary support structures;
- Installation of a proven outside wall insulation by an experienced contractor;
- Placement and removal of concrete forms; and
- Final finish with plaster, internal insulation, paints and decontamination finishes, where required.

Some of the most important aspects of these activities are the detailed planning, scheduling and control by the site management, including periodic updating of schedules and weekly internal status meetings.

Usually the peak of concrete work occurs during the first year of construction and the peak for interior finish and masonry work is in the third year. The overall manpower requirements for civil construction will generally peak during the second and third year of construction after which they will gradually decline. During the peak period around 1000 to 1200 skilled people would be required.

Although the use of modern construction equipment is essential to meet the quality standards and the schedule, up to twice as much skilled people may be required because of local conditions and qualification of construction workers. On the other hand, there are examples of having constructed NPP with less than a thousand workers.

6.6.5. Plant equipment, components and systems installation

Before these tasks are started, three major requirements have to be fulfilled for any area on the building floor where an equipment component or system has to be installed. These are:

- The interior finish of the rooms should be completed as much as possible, including decontamination paint, clean conditions or floor-seals (where needed), pedestals, anchors and concise interior 'as-built' measurements and markings of reference points;
- Documentation on vessels, pumps, valves, pipes, cranes, ventilation and electrical equipment to be installed should be completed. At headquarters complete component and systems engineering records, material and manufacturing records and licensing documentation must be available. At the site, delivery records with clear identification,

QA records and government regulatory compliance documents, where needed, must be available; and

- Final arrangements (layout) for the area concerned in the form of detailed building section drawings, composite drawings and/or a building model must be completed, verified and available at the site. In addition, special erection and transportation studies for major components, including the provision of temporary equipment openings and hoists, must be completed and documented.

The success, cost and schedule of component installation depends to a great extent on the prior fulfilment of the above requirements. Reliance on major corrections, revisions and back fits on these items in the middle of erection work can be very costly. Minor corrections, additional details and some improvisations are, however, to be expected and may well require experienced personnel with innovative ability. To co-ordinate, manage and expedite component installation requires an experienced team at the site of at least 25 professionals during the peak period. This team reports to the site manager. It should be in charge of employee and equipment safety and can also support construction supervision and later assist in the commissioning activities. The team leader must have had prior power plant erection experience. At least three senior staff members should possess several years' experience with similar erection work in fossil, chemical or similar plants.

The component installation will require further technical and coordination support from the equipment manufacturers and the responsible project-engineering headquarters division. Craftsmen should preferably be recruited from experienced component manufacturers and piping installation firms. Where nuclear grade qualifications have not yet been obtained, timely training and qualification (possibly also the corresponding costs) have to be considered. With the exception of the rare case of a large utility possessing a workforce of qualified craftsmen, one or more contracts should be awarded, preferably for entire systems, to qualified erection firms for installation and functional testing. The actual splitting of this work among several sub-contractors would not cause problems as long, as the essential coordination and support functions for this activity are executed by an experienced professional team.

For equipment, component and systems erection and installation, a peak workforce (about four years after construction start, earlier with the Advanced Reactor Construction Technologies and Schedules) of the order of 1300 people (mostly technicians and craftsmen) would be required. Many of the welders must be qualified for specialized cover-gas equipment. At least 30% of the mechanical technicians and 10% of the electricians should have knowledge and familiarity with relevant codes, standards and criteria. For difficult sites (climate, high rate of personnel turnover, low worker efficiency) the overall quantity of manpower could be 20 to 50% higher, or it can easily double [17].

Core components erection is of a special nature and requires precision tolerances and aligning to close accuracies. Qualification of procedures by mock-ups and qualification of personnel are important; it might be convenient to organize a special group (task force) for this. This stage of the construction provides the best possible opportunity to complement the training of the future plant maintenance personnel, who should actively participate in the erection and installation effort and would thus gain further experience. In addition, the contractors and sub-contractors and their skilled personnel would provide a very valuable manpower source for future plant maintenance and, in particular, for major overhauls, repairs or modifications.

6.7. Plant commissioning and acceptance

Commissioning involves all activities required for testing the operational capability of the plant and for determining the safety, efficiency and reliability of operation of individual systems and components as well as of the plant itself as defined in the engineering documentation and in the safety and reliability analysis. It includes functional and pre-operational tests, measurements, test runs and adjustments.

Although the commissioning and operation of a NPP is not much more difficult than that of a fossil plant, all tests on a NPP must be documented and performed in accordance with written, approved procedures. The major effort is not so much in the performance of the tests themselves, but in their preparation, documentation and evaluation. An early start on documentation, combined with a properly planned schedule, ensures that the major portion of the commissioning task is accomplished well ahead of the final plant acceptance. Data and procedures affecting the control, operation and maintenance of individual plant systems and components should be proven by tests during the pre-operational stages, to ensure the correctness and effectiveness of the commissioning procedures.

6.7.1. Commissioning programme

The major part of NPP commissioning covers a period of about two to three years from the finished erection of the first systems (electrical energization) up to the start of the commercial operation of the station. About 40 to 50 professionals are usually assigned to perform the tasks for this activity. Major support is to be provided by engineers and technicians of the equipment manufacturers. In addition, the plant operation and maintenance personnel participate actively in the commissioning of the plant; such participation is in fact considered to be the last essential part of their training. In general, the commissioning stage provides an excellent opportunity for on-the-job training of professionals, technicians and craftsmen.

Establishment of commissioning control points (CCPs) as part of the overall Project Schedule define the main targets of the commissioning group. These are established in order to check and confirm that the plant systems required to support their release to operation were duly commissioned and the results documented. Often, several of these are set as hold points by the regulatory body. Their formal authorization is necessary before commissioning can proceed further.

The commissioning programme is divided into successive stages to ensure the completion of all commissioning tests and the control of the logical test sequence. A formal review should be performed after completion of tests in each stage. The review will allow for a reliable judgement of the test results to determine whether the tests in the succeeding stage should proceed or should be modified.

6.7.2. Commissioning organization

6.7.2.1. Introduction

After the components and equipment are installed in the plant, a preoperational and start-up testing programme is implemented by an experienced team. The commissioning organization usually includes a number of commissioning groups for testing of different systems and the overall plant. A commissioning group is usually a composite team, made up of construction, erection and operating personnel from, for example, the equipment supplier, main contractor, A/E and the plant owner. During the plant commissioning stage it is necessary to have trained staff (150 to 250) and the active participation of the operation and maintenance team to ensure familiarization with the plant and to effect a smooth transition of responsibility. Upon completion of the commissioning tasks, these people will generally return to their original organizations.

The commissioning manager should formally take over the overall responsibility for the entire plant from the site manager normally prior to the first hot functional test. Operation of the plant systems and the entire plant during commissioning should be performed by suitably trained and qualified operating personnel, provided by the operating organization and integrated into the commissioning programme. The following services are also necessary to be provided by the operating organization to the commissioning organization:

- Maintenance, including personnel and workshops; and
- Support services such as chemistry control and radiological protection.

6.7.2.2. Commissioning functions

An example of a commissioning organization is a commissioning organization divided into four distinct functions:

- Commissioning Technical function consisting of six separate departments: namely Nuclear Steam Plant (NSP) Process, NSP I&C, Fuel Handling, Electrical, Common Services and Thermal Cycle. They are responsible for the development and implementation of a commissioning programme to demonstrate that plant structures, systems and components met their design requirements before they are declared available for service.
- Commissioning Execution function consisting of six Commissioning Execution Groups (CEG) (for each Unit and Maintenance Department, in the case of more than one unit station), one corresponding to each of the six Commissioning Technical Groups. They are responsible for performing field commissioning as defined by the Commissioning Technical Departments using the resources of the Operating and Maintenance Departments and of others as may be required (equipment suppliers, main contractor, A/E).
- Production function consisting of five separate departments: namely Operation, Maintenance, Chemistry Control, Health Physics and Nuclear Safety. The Operation and Maintenance Departments are responsible for performing normal plant operation and maintenance and for executing field commissioning. The Chemistry Control Department performs normal chemistry analysis and control functions, and supports commissioning activities. The Health Physics Department performs normal radiation protection, dosimetry, industrial safety and emergency preparedness functions, and supports commissioning activities. The Nuclear Safety group is responsible for developing the reactor physics and thermo-hydraulics commissioning programme and for providing technical support to commissioning execution/operating staff to conduct these tests.
- Planning function responsibility is to develop an optimised and integrated commissioning logic based on commissioning procedures. This logic is then used to schedule the turnover of systems from construction to the maximum extent practicable. Planning is also responsible for developing and implementing a computerized database for work management system to schedule field execution of commissioning activities as well as emerging breakdown work. Planning issues a weekly plan that formed the basis for daily plan for commissioning execution groups to perform fieldwork.

6.7.3. Technical support

The typical mission of the technical support (TS) is to assist the owner/operator management in the achievement of operational performance objectives of the NPP. In particular it is needed to have at disposal qualified staff capable of, and dedicated to, providing technical analysis and advice to support over the long term, i.e. during stage 4: Plant Operational and Life Management, and stage 5: Decommissioning. But the need for developing TS expertise arises earlier, during design and commissioning activities undertaken in stage 3: Project construction. For that reason, organizational foundations for TS function should be established early in the development of the plant and key personnel selected.

During the stage 3 Project construction, senior TS staff should be in very close contact with plant vendors and designers in order to ensure that the particular and specific opinions and requirements of the operating organization are represented and given due consideration. Commissioning is often conducted by the operating organization. In this situation TS staff should posses the best knowledge of the plant design and its operating characteristics and therefore be in a position to offer system training to operating and maintenance staff. TS should also be in position to implement the commissioning process and oversee its execution.

6.7.4. Turnover to operation

Turnover (T/O) is generally an administrative action by which responsibility for physical, economic control and for safety of the plant systems, areas and the whole plant is transferred from commissioning to the operating organization.

The operating organization should be responsible for establishment of the system turnover procedures, which should clearly identify the participants, responsibilities, duties and documents necessary for the T/O process. T/O documents should describe boundary, deficiencies and exceptions existing at the time of T/O in comparison with the requirements of the commissioning programme and test procedures.

The operating organization should receive all of the complete and update system T/O packages on time, including changes and revisions of the commissioning programme and testing procedures. The operating organization should carefully review the T/O documents and assess the test results.

T/O should be made with a minimum of, or no, exceptions or incomplete item. Experience has shown that, eliminating exceptions requires a much larger effort than working to make a complete system T/O. Decision for acceptance of additional exceptions should be made at the upper management level. T/O exceptions should be tracked and corrected in a timely manner.

Responsibilities for closing the exceptions after T/O should be clearly defined, including performance and control of the construction work and commissioning testing on the incomplete components or systems. The system T/O and the area or room T/O should be separated from each other. The system T/O, which may go through several areas or rooms, should be given first priority. The area or room T/Os can be delayed because the process of getting administrative clearances for keys and others can become very cumbersome and time consuming.

6.8. Lessons learned

Building on the experience accumulated and lessons learned during the implementation of NPP projects have shown that the followings improvements contribute to reducing construction and commissioning time:

- The project management team should be given full authority to successfully complete the project within the project budget and schedule;
- Use of a project team that actively controls the finance, schedule, and quality of the project through audits and updates. The team should be experienced and have the flexibility and ability to make adjustments during implementation. The team should be established at the early stage of the project;
- Use of Integrated Management Tools from detail design to material management and documentation control system (3D CADD, computer-controlled fabrication equipment, modelling of complete plant with as much details as possible including piping etc.);
- Good communications which can be aided by implementation of a common electronic network available to all project participants;
- Open top construction and modularization;
- Local participation should not exceed local expertise;
- Ensure that suppliers train themselves to the level of quality requirements;
- Training in scheduling techniques, management system and procedures writing, etc. is a essential part of project management responsibilities;
- There is a strong benefit in finishing design before start of construction and integrating procurement, construction and commissioning requirements with upfront design;
- In general, small incremental design upgrades usually ends up costing more than they save. It is recommended to implement design changes in planned stages rather than as they become available or even better, to freeze design as early as possible;
- Pre-qualification of contractors including design audits should be explained and agreed to beforehand;
- Separation of contracts into functional blocks (i.e. pump house, etc.) where possible, rather than by disciplines (civil, mechanical, electrical);
- Making available modern facilities and infrastructures on the site as early as possible; and
- Work (detail engineering, procurement of long delivery material, civil works) should be initiated to the extent possible before the signature of contract.

Note: Publications with additional information related to the issues covered in this chapter are listed in the Appendix III

APPENDIX I
INTERNATIONAL AGREEMENTS ON NUCLEAR POWER

The documents indicated below can be found at the IAEA's Web page:

http://www.iaea.org/Publications/Documents/Conventions/index.html

International treaties, conventions and agreements

- Treaty on the Non-Proliferation of Nuclear Weapons (NPT) INFCIRC/140;
- Guidelines for Nuclear Transfers, 1993 Revision of NSG London Guidelines;
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention), INFCIRC/205;
- International Convention for the Safety of Life at Sea;
- Convention Relating to Civil Liability in the Field of Maritime Carriage of Nuclear Materials;
- Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space and Under Water, Partial Test Ban Treaty 1963;
- Paris Convention on Third Party Liability in the Field of Nuclear Energy;
- Brussels Convention Supplementary to the Paris Convention;
- Code of Practice On the International Trans-boundary Movement of Radioactive Waste;
- The IAEA Code of Practice, INFCIRC/386;
- Code of Conduct on the Safety and Security of Radioactive Sources and the Supplementary Guidance on the Import and Export of Radioactive Sources;
- Comprehensive Nucler Test Ban Treaty;
- Convention for the Suppression of Acts of Nuclear Terrorism.

Regional treaties, conventions and agreements

- Treaty for the Prohibition of Nuclear Weapons in Latin America (Tlatelolco Treaty);
- The African Nuclear-Weapon-Free Zone Treaty (Pelindaba Treaty) including Annexes and Protocols; and the Cairo Declaration, INFCIRC/512;
- South Pacific Nuclear Free Zone Treaty (Rarotonga Treaty); reproduced in document INFCIRC/331 and Protocols,INFCIRC/331/Add.1;
- Southeast Asia Nuclear Weapon-Free Zone Treaty (Treaty of Bangkok), INFCIRC/548;
- Agreement between the Republic of Argentina, the Federative Republic of Brazil, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) and the IAEA for the Application of Safeguards, INFCIRC/435.

Safety & Security

- Convention on Early Notification of a Nuclear Accident;
- Convention on Assistance in the Case of a Nuclear Accident or Radiological;
- Convention on Nuclear Safety; Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, INFCIRC/546;
- Nordic Mutual Emergency Assistance Agreement in Connection with Radiation Accidents, INFCIRC/49;
- Convention on Physical Protection of Nuclear Material;
- Vienna Convention on Civil Liability for Nuclear Damage;
- Protocol to Amend the 1963 Vienna Convention on Civil Liability for Nuclear Damage;

- Convention on Supplementary Compensation for Nuclear Damage;
- Optional Protocol Concerning the Compulsory Settlement of Disputes to Vienna Convention on Civil Liability for Nuclear Damage, INFCIRC /500 /Add .3;
- Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention, INFCIRC/402;
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, INFCIRC/205.

Science & Technology

- African Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science & Technology (AFRA), INFCIRC/377;
- Cooperation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean (ARCAL), INFCIRC/582;
- Third Agreement to Extend the 1987 Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (RCA), INFCIRC/167;
- Revised Guiding Principles and General Operating Rules to Govern the Provision of Technical Assistance by the Agency;
- Revised Supplementary Agreement Concerning the Provision of Technical Assistance by the IAEA (RSA), INFCIRC/267;
- Co-operative Agreement for Arab States in Asia for Research, Development and Training Related to Nuclear Science& Technology (ARASIA), INFCIRC /613/Add.1.

Safeguards & Verification

- The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons - INFCIRC/153/(Corrected);
- Model Protocol Additional to the Agreement(s) Between State(s) and the Agency for the Application of Safeguards - INFCIRC/540(Corrected);
- The Agency's Safeguards System - INFCIRC/66/Rev.2;
- Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology Convention on the Physical Protection of Nuclear Material;
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management;
- Antarctic Treaty;
- Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies;
- Treaty on the Prohibition of the Emplacement of Nuclear Weapons and other Weapons of Mass Destruction on the Seabed and the Ocean Floor and the Subsoil Thereof (Seabed Treaty);
- Convention on the Prohibition of Military or any other Hostile Use of Environmental Modification Techniques (Environmental Modification Convention;
- The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies;

- Bilateral Cooperative Agreements. These agreements facilitate the exchange of scientists and engineers, exchange of information, joint research, and other cooperative activities in nuclear R&D and safety;
- For other Safeguards Agreements, check INFCIRC publications in IAEA's Web page.

APPENDIX II
EXAMPLE OF ELEMENTS TO BE CONSIDERED WHILE PERFORMING NUCLEAR POWER PLANT PLANNING

Note: The list is not exhaustive

A - ENERGY AND ECONOMIC INDICATORS

(Sources: EEDB, World Bank, WEC country profiles)

- Primary energy resources by type;
- Criteria used in assessing each resource;
- Primary energy consumption by type of fuel. Role of non-commercial fuels;
- Imports and exports of primary energy by type;
- Primary energy resource consumption by sector (industry, transport, residential, commercial, non-energy use, other) and type of fuel;
- Energy use for electricity production by type of fuel;
- Total electricity production by origin (solid fuels, oil, gas, hydro, others);
- Imports and exports of electricity;
- Primary energy and electricity consumption per capita and dollar GDP;
- CO2 emissions of the energy sector;
- Population, growth rate, population density, major urban areas;
- GDP trends over past 10–15 years. GDP by sector (agriculture, industry, manufacturing, services);
- Central government revenue and expenditure by major sectors;
- Total external debt. Debt service as % of GDP;
- External trade balance. Major imports and exports;
- Major sources of revenue.

B - ELECTRICITY GENERATING AND TRANSMISSION SYSTEMS

(Sources: Country and IAEA studies, World Bank and UNDP reports)

- Total electricity generating capacity by origin (coal, oil, gas, hydro, others).
- Electricity generating units with name, location, fuel, capacity. In particular recent big units in operation or under construction with information on origin, financing, share of local participation.
- Transmission grid diagram, including major generating units, interconnections, voltage levels, transmission capacities.
- Decided plans for expansion of generating capacity and transmission grid.

C - ENERGY AND ELECTRICITY PROJECTIONS

(Sources: Country and IAEA studies, World Bank reports and WEC national energy data)

- Recent energy and electricity demand and supply projections, including information on:
  - scenarios considered and assumptions on which they are based;
  - results.
- Projected evolution of energy system to meet demand:
  - non-electric;
  - electric.

D - ELECTRICITY SYSTEM ANALYSIS FOR PLANNING METHODS IN USE
(Sources: Country and IAEA studies and World Bank reports)

- Basic approach used in energy planning (e.g. driven by demand, by investment or supply possibilities, by social development goals).
- Methods used in economic analysis and forecasting.
- Methods used in energy and electricity demand analysis and forecasting.
- Models and methodologies used for electricity system expansion studies.
- What role have environmental considerations played in planning? How have they been incorporated?
- By which organization(s) were recent economic projections and energy and electricity expansion studies performed?
- How frequently are studies up-dated?
- Interface between energy and electricity expansion studies and national development plans.

E - ENERGY AND ELECTRICITY SUPPLY POLICIES
(Sources: Country reports, reports from IAEA, World Bank, UNDP)

- National development policies and plan.
- Implementation mechanisms for national development plan.
- National policies for the energy and electricity sectors. Perceptions of major constraints. Priorities.
- Electricity tariff policies.
- Environmental protection policies and their impact on the energy sector.

F - NUCLEAR POWER PLANNING AND PRE-INVESTMENT STUDIES
(Sources: Country studies, IAEA studies, and World Bank and UNDP reports)

- Has the nuclear option been included in electricity system expansion studies? Results?
- Have any decisions on nuclear power use been taken at a policy level (executive level in utility or AEC, ministry, government)?
- Organisation which performs nuclear power planning. Interfaces with others.
- Unit sizes and types considered. Timing of introduction on grid.
- Site(s) considered. Site evaluation.
- Assessments of infrastructures and assumptions about national participation.
- National infrastructure development policies and plans.
- Nuclear power project pre-investment study, when and performed by whom? Results?
- Subsequent policy actions or decisions.

G - LAWS CONCERNING RADIATION PROTECTION, NUCLEAR SAFETY AND PLANT/MATERIAL OWNERSHIP

- International treaties, conventions and arrangements, see Appendix I
- Law and regulations for radiation protection
- Law and regulations for safety of nuclear installations

- Compatibility of national radiation protection and nuclear safety regulations with IAEA codes and guides.
- Law and regulations for ownership of nuclear installations and materials.
- Law or policy concerning nuclear third party liability.
- Party to NPT, regional treaties/conventions/agreements, Safeguards agreement with the IAEA?
- Bilateral nuclear supply agreements.
- Conventions on early notification and assistance.
- Physical protection convention.
- Nuclear safety convention.
- Convention on safety of waste and spent fuel management.

H - ORGANIZATIONS AND MINISTRIES INVOLVED

In each case specific responsibilities, work performed and competence for:

- Energy and electricity demand forecasting.
- Energy and electricity system expansion planning.
- Nuclear power planning. Which organisation would be owner/operator of plant? Interfaces.
- Regulation of safety and radiation protection.
- Nuclear R&D.
- Environmental protection. Interface with energy use.
- Promotion of industrial standards and QM/QA.
- System of standardisation, accreditation and certification.

I - DECISION-MAKING FOR POWER PROJECTS

- Which organizations have decided and now decide on new power projects and on what bases? Subject to approval? By whom?
- How is financing decided?
- Interface with national development plan and priorities.
- Plant import policies. Constraints and restrictions.
- How are decisions taken on national participation?
- How would decisions on a nuclear power plant project be different?

J - FINANCING OF RECENT POWER PROJECTS
(Sources: World Bank reports, regional development banks, IAEA reports)

- Financing mechanisms used for recent (last 5 years) major power plant projects.
- Mechanisms for international financing.
- Mechanisms for local financing.

K - PUBLIC OPINION, ENERGY AND NUCLEAR POWER

- Public opinion movements influencing energy and electricity sector decisions.

- Public information programme concerning energy.
- Public information programme concerning nuclear power.

L - AVAILABILITY OF HUMAN RESOURCES

- Professionals/technitians in the nuclear field.
- Experience managers
- Training institutions

APPENDIX III
CHAPTER RELATED PUBLICATIONS

Chapter 2

- INTERNATIONAL ATOMIC ENERGY AGENCY, PRIS: Power Reactor Information System, IAEA, Vienna (published every year)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Fundamentals Principles, Safety Fundamentals No. SF-1, IAEA, Vienna (2006)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Culture (A Report by the International Nuclear Safety Advisory Group), INSAG Series No. 4, IAEA, Vienna (1991)
- See Appendix I

Chapter 3

- INTERNATIONAL ATOMIC ENERGY AGENCY, Energy and Nuclear Power Planning in Developing Countries, Technical Report Series No. 245, IAEA, Vienna (1985)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Power Programme Planning: An Integrated Approach, IAEA-TECDOC-1259, IAEA, Vienna (2001)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Staffing requirements for future small and medium (SMRs) based on operating experiences and projections, IAEA-TECDOC-1193, IAEA, Vienna (2001)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Management of problematic waste and material generated during the Decommissioning of Nuclear Facilities, Technical Report Series No. 441, IAEA, Vienna (2006)

Chapter 4

- INTERNATIONAL ATOMIC ENERGY AGENCY, Manpower Development for Nuclear Power: A Guidebook, Technical Report Series No. 200, IAEA, Vienna (1980)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Introduction of Nuclear Power: A Guidebook, Technical Report Series No. 217, IAEA, Vienna (1982)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Expansion Planning for Electrical Generating System, Technical Report Series No. 241, IAEA, Vienna (1984)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Energy and Nuclear Power Planning in Developing Countries, Technical Report Series No. 245, IAEA, Vienna (1985)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Promotion and Financing of Nuclear Power Programmes in Developing Countries, STI/PUB/777, IAEA, Vienna (1987)
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- INTERNATIONAL ATOMIC ENERGY AGENCY, Introduction to Nuclear Desalination, Technical Report Series No. 400, IAEA, Vienna (2000)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Siting of Nuclear Facilities, Proceeding Series, STI/PUB/384, Vienna (9-13 December 1974)

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- INTERNATIONAL ATOMIC ENERGY AGENCY, Site Evaluation for Nuclear Safety Installations, Safety Standard Series No. NS-R-3, IAEA, Vienna (2003)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Basic Infrastructure for a Nuclear Power Project, IAEA-TECDOC-1513, IAEA, Vienna (2006)
- INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA-TECDOC-1522 Potential for Sharing Nuclear Power Infrastructure between Countries, IAEA, Vienna (2006)
- INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Facilities and Activities Safety Requirements, Safety Standards Series No. GS-R-3, IAEA, Vienna (2006)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Management System for Facilities and Activities Safety Guide, Safety Standards Series No. GS-G-3.1, IAEA, Vienna (2006)

Chapter 5

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- INTERNATIONAL ATOMIC ENERGY AGENCY, Configuration Management in Nuclear Power Plants, IAEA-TECDOC-1335, IAEA, Vienna (2003)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Construction and Commissioning Experience of Evolutionary Water Cooled Nuclear Power Plants, IAEA-TECDOC-1390 (2004)
- INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Facilities and Activities Safety Requirements, Safety Standards Series No. GS-R-3, IAEA, Vienna (2006)
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ABBREVIATIONS

A/E	architect engineer
BIS	bid invitation specifications
BOP	balance of plant
BWR	boiling water reactor
EEDB	Energy Economics Data Base
ER	environmental report
FBR	fast breeder reactor
FSAR	final safety analysis report
GCR	gas cooled reactor
HLRW	high level radioactive waste
HTGR	high temperature gas reactor
HWR	heavy water reactor
IDC	interest during construction
LMFR	liquid metal cooled fast reactor
LWR	light water reactor
MAED	Model for Analysis of Energy Demand
MOX	mixed oxide
NDE	non-destructing-examination
NPP	nuclear power plant
NPPPS	nuclear power plant planning study
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
NSSS	nuclear steam supply system
O&M	operation and maintenance
PHWR	pressurized heavy water reactor
PRIS	Power Reactor Information System
PSAR	preliminary safety analysis report
PWR	pressurized light water reactor
QA	quality assurance

QM	quality management
R&D	research and development
SOR	safety option report
T/O	turnover
TG	turbo generator
TS	technical support
UNDP	United Nations Development Programme
WANO	World Association of Nuclear Operators
WEC	World Energy Council
WNA	World Nuclear Association
WWER	water cooled water moderated power reactor

CONTRIBUTORS TO DRAFTING AND REVIEW

Abdel Hamid, S.B.	Advisor, Minister of Electricity and Energy, Egypt
Boucher, R.	Consultant, Canada
Condu, M.	International Atomic Energy Agency
Diaz, E.	Consultant, Argentina
Facer, R.I.	International Atomic Energy Agency
Godoy, A.	International Atomic Energy Agency
Gueorguiev, B.	International Atomic Energy Agency
Han, K-I.	Korea Engineering Company, Republic of Korea
Koorapaty, M.R.	Consultant, India
Lignini, F.	International Atomic Energy Agency
Niehaus, F.	International Atomic Energy Agency
Pieroni, N.	International Atomic Energy Agency
Rotaru, I.	Societatea Nationala Nuclearelectrica SA, Romania
Vergara, J.	Chilean Nuclear Energy Commission, Chile

Consultants meetings

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