IAEA-TECDOC-1259

Nuclear power programme planning: An integrated approach

INTERNATIONAL ATOMIC ENERGY AGENCY

IAEA

December 2001

The originating Sections of this publication in the IAEA were:

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Planning and Economic Studies Section
International Atomic Energy Agency
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A-1400 Vienna, Austria

NUCLEAR POWER PROGRAMME PLANNING:
AN INTEGRATED APPROACH
IAEA, VIENNA, 2001
IAEA-TECDOC-1259

ISSN 1011–4289

Printed by the IAEA in Austria
December 2001

FOREWORD

The International Atomic Energy Agency (IAEA) has published material on different policy considerations in the introduction of nuclear power, primarily addressed to top level decision makers in government and industry in Member States. Several Member States and experts recommended to the IAEA to address the aspects of an integrated approach to nuclear power programme planning and to serve as guidance to those countries wishing to embark on a nuclear power programme. As a follow-up, the present publication is primarily intended to serve as guidance for executives and managers in Member States in planning for possible introduction of nuclear power plants in their electricity generating systems.

Nuclear power programme planning, as dealt with in this publication, includes all activities that need to be carried out up to a well-founded decision to proceed with a project feasibility study. Project implementation beyond this decision is not in the scope of this publication. Although it is possible to use nuclear energy as a heat source for industrial processes, desalination and other heat applications, it is assumed in this publication that the planning is aimed towards nuclear power for electricity generation. Much of the information given would, however, also be relevant for planning of nuclear reactors for heat production.

The publication was prepared within the framework of the IAEA's programme on nuclear power planning, implementation and performance as a joint activity of the Nuclear Power Engineering Section and the Planning and Economic Studies Section (Division of Nuclear Power). The IAEA wishes to thank all contributors to this publication. The responsible IAEA officer was K.V. Mahadeva Rao of the Division of Nuclear Power.

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1. INTRODUCTION

1.1. Structure of the TECDOC

The first part of the TECDOC outlines the stages of nuclear power programme planning, the approaches, decisions and various activities to be carried out by different national agencies associated directly or indirectly in the nuclear power programme. It covers the activities from the beginning of conceiving a nuclear power programme up to the stage of a well-founded decision for a project feasibility study. It presents a sequential and integrated approach to nuclear power programme planning. The second part of the TECDOC discusses important areas of nuclear power for which policy decisions need to be taken. It provides information in these areas to enable arriving at a decision that is best suited for the country. Examples of experience in nuclear power programme planning in some Member States are included as the annexes.

The International Atomic Energy Agency (IAEA) has published books on different policy considerations for the introduction of nuclear power [1–8], that have been used as a background for the present publication and are referred to wherever relevant.

1.2. Definition of integrated approach

An integrated approach to planning a nuclear power programme should consider all alternatives and relevant factors that influence the programme, such as: long-term energy and electricity expansion strategies, financial requirements, infrastructure including that for regulating nuclear safety and radiation protection, government policies and commitments, organizational co-ordination, overall manpower development, legal framework, public information and acceptance, external technical assistance, and compliance with international agreements.

1.3. Objectives of the TECDOC

The objective of this technical publication is to provide guidance to Member States on an integrated and sequential approach to nuclear power programme planning. This covers the activities from the beginning of conceiving a programme up to the stage of a decision by the country to proceed with the project feasibility study and excludes project implementation. The developing countries primarily addressed in this publication are those, which do not have nuclear power plants either in operation or under construction. They also have not taken a definitive decision to forego the nuclear power option.

Although it is possible to use nuclear energy as a heat source for industrial processes, desalination and other heat applications, it is assumed in this publication that the planning is aimed towards nuclear power for electricity generation. Much of the information given would, however, be relevant also for planning of nuclear reactors for heat production.

2. THE NUCLEAR POWER OPTION

2.1. Background

At the end of the 20th century, nuclear energy supplied about 16% of the world electricity needs [9]. The growth of nuclear power in the developing countries has so far been limited as compared to the industrialised countries [10, 11]. The accidents at Three Mile Island, and Chernobyl and also the globalisation and deregulation of energy and electricity markets, have led to stagnation in the growth of nuclear power. At the same time, safety of nuclear power plants (NPPs) has seen continuous up-gradation to address emerging concerns. Various international conferences [12–14] have repeatedly highlighted the environmental concerns and the need for strategies for sustainable development, including the need for reducing the emission of greenhouse gases.

2.2. Future role of nuclear power option

The electricity demand is expected to grow at a rapid rate in the next few decades in the developing countries [9]. This is mainly due to the close relationship of the growth in electricity demand with the development of the quality of life of the population. The industrialised countries also need to add electricity generation capacity to replace ageing and retiring units. The options available to meet electricity demand should take into account factors such as energy security, diversity in energy sources for electricity generation and environmental protection. Long-term stability of fuel prices is also another key factor as fossil fuel prices represent a high percentage of the cost of the electricity produced, whereas the cost of nuclear power is less sensitive to variations of nuclear fuel prices. The future role of nuclear power has to be seen in the context of the above factors.

If additional electricity generating capacity is urgently needed, gas, oil or coal fired power plants can be planned and constructed more quickly than nuclear power plants. This is due to the fact that the planning and execution of a nuclear power project require longer lead-times and also pose special demands on related infrastructures. Such an approach of quick addition of fossil fuel power plants for urgent needs is possible provided the country is endowed with, or has easy access to, fossil fuel energy resources. However, this approach cannot be a continuing and long-term solution from environmental considerations of CO_2 releases from the fossil fuel power plants.

Nuclear power is considered to be a valid option for electricity generation if its special characteristics are taken into account and the requirements it poses can be met, especially for the maintenance of a very high level of safety. It is one of the objectives of the IAEA to assist its Member States to take the decision on whether to use the nuclear power option or not. The decision will largely depend on the situation in the country and the policies developed by its authorities and government.

2.3. Specific characteristics of NPPs

The specific characteristics to be considered in the planning of a nuclear power programme are:

- NPPs generate virtually no CO_2 and, even if the whole nuclear fuel cycle is considered, the amounts are very small. Therefore, nuclear power could play an important global role when the issue of climate change is considered.
- Nuclear power can help to achieve energy security by way of independence from energy imports since it is relatively easy and economical to store the amount of nuclear fuel needed for several years of NPP operation. It provides diversity in energy resources for electricity generation and it is a valid long-term option.

- The independence from energy imports is obtained through investment in advanced technology. This in turn could result in the introduction of other high technologies as well. The spin-off benefits to the industrial sector include up-gradation of quality levels and manpower skills, introduction of safety culture and discipline for adhering to procedures.
- In order to obtain nuclear technology and nuclear materials from international source, the recipient country's position in terms of nuclear non-proliferation (NPT) and willingness to accept bilateral or IAEA administered full-scope a facility safeguards need to be addressed.
- NPPs require relatively higher capital investment as compared to fossil fuel plants. In the early stages of a nuclear power programme there will be additional investments and extra costs for setting up the needed organisations; NPPs can however contribute to maintaining long-term stability of electricity generation prices.
- Special legislation and standards are required for radiation protection and nuclear safety.
- An NPP is technically very demanding in the quality of design, construction and operation. As a consequence, assistance from abroad in the form of a long term agreement/contract might be needed after the initiation of a nuclear power programme. One of the important decisions will concern the question of how far a country should seek to be independent and how outside support should be arranged. This will depend on the industrial infrastructure of the country.
- There is a small risk of accidents that could have large consequences[1]. The plant owner is responsible for plant safety and has to accept liability usually backed by the Government beyond a given value.
- Because of the above, the operators of the NPPs must maintain insurance or other financial security for an amount corresponding to the operator’s liability. If such security is insufficient, the State is obliged to make up the difference up to the limit of this liability.
- Radioactive wastes from NPPs have to be managed safely and ultimately disposed of in a safe manner for which technology is available and continuously being improved. A global approach might contribute in converging to a solution.
- For the success of a nuclear power programme, it is of paramount importance to have a clear government/national commitment prior to its launching.
- With respect to the need for nuclear power as a component of the overall energy mix, it should be born in mind that building one single unit of a nuclear power plant is often not profitable in view of the large fore-cost (initial investment in the preparation of the programme and the first project) involved in it. Therefore, the intending developing country should aim at a nuclear power programme and not a mere nuclear power project. A programme would fetch many tangible, intangible and spin-off benefits from a nuclear power programme, thereby making contributions to not only the energy sector but also to the overall economic activity.

2.4. Related issues

If electricity system planning is to include the nuclear power option in a realistic manner, the country should have an adequate total installed power capacity, in an integrated grid, of over 7–10 times the unit size of the NPP. Electricity grid size, grid mix, the extent of interconnection and the need for strengthening the grid stability are important considerations in the assessment. In addition, the country should have the expectation of a steadily increasing electric power demand, or a need to replace older units, in the medium term. These

[1] Current plant designs make the risk extremely small.

requirements are intrinsic to the planning of the country's electric power system [15, 16]. Experience indicates that a utility serving such a grid already would have a planning group with some experience in using advanced methodologies for economic optimisation of long-term generating capacity additions. Economic optimisation and technical characteristics are only part of the considerations in electric power system planning. It should be recognised that national policies have a major influence in planning. Hence the decision making process does not only concern these technical and economical aspects, which are in the domain of competence of utilities/generating agencies, but also other factors as well. Other main factors to be taken into account are security of energy supply, social aspects and impact on the environment. Nuclear power has a central role to play if greenhouse gas emissions are to be limited.

The future prospects of nuclear power are related to a few issues that must be resolved. The most important issue is public confidence — or at least public tolerance — particularly on an accepted solution to the disposal of high level waste. The second, no less important, is competitiveness in terms of capital costs and construction periods. A third issue is to identify the appropriate linkages (through the marketplace or regulations) between nuclear power and environmental issues, such as global climate change, local air quality and regional rain acidification. Lastly, there is the need for a global approach to some activities of nuclear power, such as nuclear waste management. These issues are related to the country's energy policy and international co-operation and therefore belong to the governmental domain of competence.

The influence of national policies is predominantly pronounced in the case of nuclear power, which is encountering serious problems of public and political opposition in a number of industrialised and developing countries. As a result, national policies regarding the use of nuclear power should be developed with care. Policy decisions should be taken with the best possible information background and with full transparency so that, as far as possible, external political considerations do not affect them. Accordingly, this publication discusses at some length the subject of how the important policy decisions are taken and what should be the background for such decisions.

The special characteristics of nuclear power mean that nuclear power planning should be seen in the context of the development of a long-term, national energy policy framework which could result in a commitment to a nuclear power programme involving the construction of several plants over a period of time.

3. REQUIREMENTS FOR NUCLEAR POWER PROGRAMME PLANNING

3.1. Definition of requirements

Nuclear power is a demanding technology, which poses strict demands on infrastructures, to an extent that is not likely to have been experienced in other industries in a given country. It entails multidisciplinary inputs with R&D backup. Specific requirements will constitute constraints on the introduction of nuclear power, if they are not met [1–3]. These requirements are to be found in the following main areas:

- Government policies and national commitment;
- Action Plan for introduction of the first NPP and its integration into the national planning framework;
- Organisational structures and competence for energy and electricity system planning;

- Institutional and organisational structures for independent regulation of radiation protection and nuclear safety [17, 18] and for plant ownership, both with highly qualified and appropriately trained staff [19, 20];
- Adequate supporting infrastructures in industry [7], R&D [21], manpower development [20], technology transfer and quality management/quality assurance (QM/QA) [22];
- In order to obtain nuclear technology, and supply of nuclear equipment, materials and services, international agreements (implies nuclear safeguards) need to be concluded.
- Financing [1, 2, 3].

The government decision should carry in itself a stable and continuing commitment for the long-term, since only a long-term nuclear power programme, involving several plants over a period of time, can justify the efforts and costs which will have to be devoted to national infrastructure strengthening and development. Decisions on nuclear power projects can be made only in the context of a long-term economic electricity generation expansion plan, which will call for long-term policy decisions for financing, and for conditions for international supplies of technology and nuclear fuel cycle services, including waste management and disposal. There are many ways through which a government could formalise its own commitment to a nuclear power programme development (for instance, laws, decrees or other legal instruments). It is important, from technological and financing considerations, to attract foreign suppliers and financial institutions to take part in the implementation of the programme.

The following criteria are fundamental in a country's programme planning process. The decisions are to be based on:

(i) Technical feasibility and economic viability of nuclear power as a long-term energy supply expansion strategy, considering all alternatives and relevant factors;
(ii) Comprehensive planning, covering all aspects and taking adequate steps for meeting all necessary supporting infrastructure with assured financing;
(iii) Taking adequate measures for effective project management, aiming at a timely completion of the first nuclear power project within the estimated cost and operating it safely and reliably once in service.

Nuclear power planning must go far beyond technical and economic planning, and will require a large number of studies, including assessment of national infrastructures and, where relevant, development of plans for strengthening them, as a prerequisite for formulation of government policies and commitments. This is the basic reason why it is necessary to take a long-term approach and to implement an integrated framework for planning a nuclear power programme. A large number of activities in a number of national organisations will have to be included in the overall planning work. Co-ordination of all activities should be a key function. Defining an integrated framework should be based on a broad assessment of the capabilities in the country, in order to find out where deficiencies can be found, as well as how to correct them. The end result would be an overall policy decision, which could be either to develop the nuclear power option with the relevant long-term commitment, or not to pursue it in the near term.

Every option has its own technical and economic characteristics and environmental and social issues. All options should be considered until a policy decision explicitly excludes one of them. Nuclear power is special with regard to appropriate provisions to cover nuclear liability in the case of a major accident, which is however associated with a very low probability. In spite of such a very low probability, an appropriate legal framework to cover the economic liability for a nuclear accident should be put in place, as this may be a requirement from existing international agreements. It is also special due to the unavoidable dependence on assistance from abroad and on the functioning of the international market for the supply of technologies and services. Many of these issues appear as well in other forms of power generation, like hydropower, fossil fuel thermal power, etc. Hydropower is like nuclear in that it has a potential for accidents with consequent liability questions, and it can have, for its implementation, major local environmental impacts, including dislocation of large populations. Thermal power plants involve environmental impacts not only on a local level but also on regional and international levels, and may increase dependence on imported fuels. Even on domestically available fossil fuel resources, infrastructure for mining and transportation can be significant.

In order to meet the need for progressively increasing energy demand, particularly for electricity, which is driven largely by growing population needs and economies in developing countries, and by the objective of achieving energy security, appropriate energy policies have to be developed. It may be prudent not only to look into the country's own electricity demands but also into those of neighbouring countries, and to keep the option of export/import of electricity open. The threat of global warming and climate change and the need to mitigate the emission of man-made greenhouse gases are issues that need to be taken into account.

3.2. A sequential approach to nuclear power programme planning

Before a decision to include nuclear power in the planning of electricity system expansion, an enhanced electricity system analysis for decision making [23] is necessary which among others also addresses health and environmental impacts (Table I).

Once a policy decision is made to include nuclear power as an option in the energy mix of the electricity system expansion plan, the nuclear power planning needs a sequential approach [5–8] as detailed in Table I.

A simplified, sequential approach to nuclear power planning is shown in Table I. It is built around the significant decisions that will have to be taken as work progresses. In most cases, the decisions indicated in Table I would not have been taken as individual "milestones", but rather as part of more extensive decisions. Also, there may not be a clear sequence of activities, since actions under the different stages may run in parallel.

The stages shown in Table I represent very different levels of commitment to the nuclear power option. Stage A would, in most cases, not be tied specifically to the preparations for nuclear power, but is a normal development of planning capabilities in a country with a sizeable generating capacity and grid to be served. It is described here since this competence is one of the necessary bases for the nuclear power planning work, when it has been decided to include the nuclear power option.

Stage B will include studies and assessments, which are directed more specifically towards a nuclear power programme but it does not mean that a commitment to launch such a programme has been made. However, since this will be the likely beginning of public and political discussions about the nuclear power option, particular attention should be given to the need for public information that clearly presents the rationale for nuclear power in comparison with other energy options. This is of particular importance since this stage includes the start of site surveys, which means that local populations will be involved and it will be necessary to demonstrate that the decisions taken so far are based on solid and sound policies.

Table I. Sequential approach to nuclear power programme planning

STAGES	APPROACH	OBJECTIVE
A. CREATING THE BASIC PLANNING COMPETENCE	• Setting up the competent organisations for general analyses for planning of energy and electricity system expansion. • Providing the policy framework for energy security and analyses for planning, including how to take health and environmental impacts into account. • Developing of long-term economic electricity expansion plan. • Examining the possibilities for including the nuclear power option in optimised electricity system planning.	***TO INCLUDE NUCLEAR POWER OPTION IN PLANNING***
B. EXAMINING THE NUCLEAR POWER OPTION	• Examining the framework that would be needed for nuclear power introduction, including infrastructure status and development requirements. • Reviewing possible sources of assistance for setting up NPP. • Start site surveys.	***TO REVIEW RELEVANT ISSUES RELATED TO NUCLEAR POWER***
C. DEVELOPING THE NUCLEAR POWER OPTION	• Develop the policies needed for nuclear power introduction, including infrastructure development, safety, waste management, financing, national participation and technology transfer.	***TO DEFINE A NUCLEAR POWER POLICY***
D. ESTABLISHING THE NUCLEAR POWER OPTION	• Establish the legal framework and major organisations. • Establish timing of nuclear power units. • Negotiate international agreements.	***TO LAUNCH A FEASIBILITY STUDY***

Manpower development at an early stage, starting at secondary school and at the university level, would not only provide for the necessary highly educated people for planning the programme but would also contribute to the education of the public at large. It is essential to give adequate attention to the curriculum of the educational institutions of the country, to provide all necessary orientation towards the topic of nuclear power. In addition, the required training infrastructure must be developed and put in place. These activities do require long time and, therefore, should be started rather early, well before launching the nuclear power programme [19, 20, 24].

Stage C stresses development of policies and will lead to Stage D that would be a firm commitment to establish the legal and organisational frameworks necessary for a nuclear power programme. The detailed actions to be taken have been already discussed extensively [1, 2, 3, 6, 7, 8, 20, 25]. These actions are summarised in Table II, for the same stages shown in Table I.

Table II represents the "integrated package" of activities that have to be performed. It is 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 organisations 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, co-ordination, follow-up, scheduling 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 organisations, each with its own established mandate, are likely to be involved and lack of co-ordination and co-operation among them could delay or even block nuclear power programming.

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 nuclear power programme planning.

The organisations [26] associated with nuclear power programme planning include the following:

— 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 [19, 20, 24], and to the use of the international market. It will have to promulgate the necessary legislation [17], establish the needed organisations 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, executing them and operating the plants safely. If this organisation is different from the utility which owns and operates other generating plants, a close co-operation and co-ordination 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 authority***, which may have to be created, with responsibilities for defining all safety requirements and supervising that they are met. As there will also be other regulatory agencies in the country involved in specific areas, e.g. safety of pressure vessels and electrical installations, pollution control and environmental protection etc. it will be essential that the roles and responsibilities be clearly demarcated between these agencies;

Table II. Actions in the early stages of nuclear power programme planning

STAGES	ACTIONS	OBJECTIVE
A. CREATING THE BASIC PLANNING COMPETENCE	• Define the organisations 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 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 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***

Table II. (cont.)

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 plants 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 programme feasibility 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***
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 feasibility study. • Start developing an adequate and stable electricity grid.	***TO LAUNCH A FEASIBILITY STUDY***

- The different ***R&D organisations***, 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 nuclear power project;
- The ***educational institutions,*** which will have to help meet the needs for highly qualified staff at all levels.

3.3. The early stages of nuclear power programme planning

3.3.1. Stage A: Creating the basic analysis competence for planning

Because of the importance of meeting future overall energy demands, many countries have a central planning commission or a similar body with the mandate for analysing energy demand and supply. Well before the nuclear power option is included in electricity supply planning, there should also exist an organisation responsible for economic and technical planning of the electricity system expansion, in the context of national energy demand and electricity supply planning [23, 27]. This organisation, or a system planning group, may be located within the electric utility sector. It is necessary to have close co-ordination and co-operation in the planning work performed by both the central planning and the system expansion organisations. If the nuclear power plants are to be owned and operated by an organisation other than the electric utility, this will even further stress the need for co-ordination in the early planning work by all organisations involved. The competence of the system planning group should be high and state-of-the-art models and methodologies should be used. Appendix 2 lists the models developed by the IAEA.

The basic objective of the planning group is to define a technically feasible and economically optimised expansion plans for the electricity system. The group will have to have access to a large amount of information and data, ranging from national development plans and energy demand trends and forecasts, to actual cost experience from generating plants and general economic parameters, including interest and discount rates for major projects. The planning results are sensitive to some of the input data, such as future fuel costs, plant capital costs and discount rate, and considerable judgement is needed in order to select realistic values. The work of the planning group, therefore, requires manpower with high qualifications and also depends on broad co-operation with specialists in a number of other national agencies (e.g. economic ministry, energy ministry and environment ministry).

The group's work will also have constraints laid down by national policies, e.g. as regards environmental protection standards, fuel policies (energy independence), resource conservation and balance of payments.

Once the central planning has decided to include nuclear power in the electricity system expansion analysis and planning, the detailed planning for the nuclear power plants has to commence [5, 6, 8].

The time horizon for nuclear power programme planning is generally in the order of 15 years, which is much longer than that used by other industries and probably longer than what has been used in the country for planning conventional power plants. Conditions will, of course, change and the planning exercise will have to be repeated. The economic planning of electricity system expansion is indeed an iterative process and a continuing, "rolling" exercise which has to be updated on a regular basis.

The results of the planning group's work will form the key input to know whether the nuclear power option has a role in an economically viable long-term energy and electricity supply expansion strategy. It has, however, been emphasised that decisions on nuclear power should not be taken only on economic grounds, but should consider a number of additional factors. It is clear from Table III that all the institutions and organisations mentioned above will have to be included in the decision making process.

Table III. Functions of Steering Committee

• Serve as authority for overall guidance of planning work;
• Distribute the defined tasks to appropriate organisations and make sure that work is performed;
• Take required decisions, within its competence;
• Prepare government policy decisions.

3.3.2. Stage B: Examining the nuclear power option

To examine the nuclear power option will require specialists in several disciplines, as shown in Table II. At this stage, only some of the specialists have to be on the staff of the organisations concerned, since part of the studies and assessments can be performed with the help of consulting firms. In most cases, there could be a lack of experience on which to base decisions and actions. It would be desirable, already at this stage, to develop close ties with organisations abroad having experience with the process, e.g. through a co-operation agreement between governments and utilities. In many of the subject areas, IAEA guidebooks are available [5, 6, 7, 8, 15, 16, 20, 21, 24, 25]. The IAEA also has developed some packages of assistance, e.g. for nuclear legislation and safety regulation, as well as planning models and methodologies. For some of the international agreements there are already binding provisions as, for example, the non-proliferation treaty (NPT). In spite of the external assistance, it is important to develop domestic capability to judge, assess and absorb such external advice/work/service, as the responsibility for the decision lies with the owner. There could be a number of organisations within a country that are specialised in specific areas and their expertise must be used where feasible.

For all subject areas, there is a common requirement for reviewing the capabilities of the existing organisations, and for defining the needs for strengthening capabilities in some cases or for setting up new organisations in other cases. Above all, it will be necessary to assess how it will be possible to assure that qualified staff will be available when needed and that it will have the necessary support and mandate to carry out the required tasks.

The likelihood that there may be some public opposition to a nuclear power programme stresses the need for establishing public information activities as early as possible. The public information group should be well informed about any on-going decision to support studies and on the progress being made in dealing with issues of concern to the public. Three subjects are likely to be especially important:

— **Nuclear safety**: It will be very desirable that the public information group can, at an early stage, provide information to the local population about the safety policies that have been established, or are proposed to be adopted, in particular with regard to siting [28], e.g. if a plant safety criterion will be that no evacuation of the local population will be necessary even in the case of a serious accident;
— **Waste management and disposal policies**: It has proven useful that waste management**,** transport and disposal operations for low level waste, e.g. from hospitals and industry, are already being carried out under regulatory supervision. The mere existence of such an operation seems to make it somewhat easier to persuade the public that spent fuel and high level waste can also be safely managed**,** transported and disposed of. Above all, the national policy to be adopted for the back end of the fuel cycle [25] should be clear at a very early stage, even if options such as co-operating in an international arrangement for disposal are kept open, in addition to national disposal;
— **Nuclear power option**: The public information group must be able to explain the justification of the nuclear power option, 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.

Even if the early stages do not involve any commitment to a nuclear power programme, there is a steady and increasing commitment to further work at each successive stage. Reviewing alternatives for nuclear safety regulation policy will mean an increasingly deep study of what these alternatives are. Another subject that is likely to be fraught with difficulty is the target for national participation in the first and subsequent nuclear power projects and the policy that should apply to it. These will be discussed in more detail in Section 5.

3.4. Developing and establishing the nuclear power option

3.4.1. Stage C: Developing the nuclear power option

The third planning stage dealing with developing the nuclear option mainly concerns the development and adoption of national policies for the nuclear sector. Areas where decisions will be needed consist of the following [1]:

— government/national commitment;
— legal regulatory framework development;
— nuclear and radiation safety regime development;
— manpower development;
— national participation in nuclear power plant projects;
— environmental aspects (only site specific, general env. aspects are included in stage a);
— financing;
— international treaties and agreements;
— nuclear fuel cycle;
— radioactive waste management;
— decommissioning;
— public acceptance;
— other applicable national policies.

At this stage, the desirable and needed co-operation with and dependence on foreign organisations also should become clear and formal arrangements should be made. At the end of this stage, decisions should be taken on all policies needed, which also will have made clear the investments that have to be made in new organisations, in strengthening existing ones and in infrastructure development.

3.4.2. Stage D: Establishing the nuclear power option

The last planning stage dealing with establishing the nuclear power option mainly concerns the establishment of the required framework and the organisations for nuclear power.

As shown in Table II, it is proposed that at the end of the fourth stage, a feasibility study should be launched for the first NPP to serve as a basis for an overall policy decision. Usually, as mentioned in Section 3.2, policy is developed through a number of decisions in different areas. Thereafter, a "white paper" or other means, which documents the completeness of the information and the policy decisions taken, could be prepared with a view to possibly making it available to the public. While the need for such a "white paper", or other means, could be decided in each individual situation, it will be desirable at this stage to document all technical, economical, financial, social and environmental aspects that have been taken into account.

3.5. Resource planning

Financial and manpower resources are the two crucial items for planning a nuclear power programme. Regarding the initial infrastructure to be set up prior to launching a nuclear power programme, costs differ from country to country depending upon the availability of infrastructures from other industries.

A most serious constraint for the introduction of nuclear power in developing countries is the difficulty in obtaining financing [3]. The OECD "consensus", which prescribes a higher interest rate for loans towards export of nuclear power plants than for other options was, in particular, considered to "representing a significant economic burden for nuclear plants". Regrettably, not much has changed since the late 1980’s and financing remains a major constraint. The World Bank still will not consider giving even "seed" financing to a nuclear power plant, although it has helped to finance some auxiliary equipment for nuclear power plants in Eastern Europe. The regional development banks have not taken any clearly defined stand on the issue. The IAEA Guidebook on Financing Arrangements for Nuclear Power Projects in Developing Countries [29] reviews the main features and problems involved in financing, approaches for financing power generation projects and for mobilizing financial resources.

The IAEA Guidebook on Manpower Development [20] gives the details on the manpower requirements and technical qualifications for all the stages i.e. pre-project activities, project management, project engineering, procurement, quality assurance/quality control, plant construction, commissioning, operation and maintenance, fuel cycle activities and nuclear licensing and regulation. The Guidebook also deals with national participation and manpower development for the same. The Guidebook gives details on manpower development programme planning, manpower development implementation and manpower development for the activities of a nuclear power programme.

4. ACHIEVING AN INTEGRATED APPROACH

4.1. Significance of the stages and decisions in the programme planning

As indicated in Table I, the following decisions, when they have effectively been taken in the relevant stages, are the most significant in the planning process aiming towards a nuclear power programme:

- The decision to include the nuclear power option in planning for the expansion of the electricity generating system;
- The decision on a policy for nuclear power application in the context of national development plans and long-term electricity supply;
- The decision to identify possible sites for nuclear power plants and waste repositories and to start evaluating them;
- The decision to launch a feasibility study.

Each of these decisions will mean that commitments have to be made. For example, the inclusion of the nuclear power option in generation expansion planning would mean that the government makes a commitment to support the nuclear power programme planning process and also imply that, if the planning studies confirm that it is technically and economically viable and if no overriding reasons to foreclose the nuclear power option appear in the course of the assessments, a tentative commitment to study a nuclear power programme in depth exists.

The decision to identify possible sites implies that the planning process is likely to come into the public domain. It would, inter-alia, indicate that electric grid characteristics and investments necessary to strengthen the grid are recognized, and that a public information programme on nuclear power needs to be launched.

The decision on a nuclear power policy should involve a definite long-term government commitment to a nuclear power programme, including a commitment of resources for the further work and at least an acknowledgement that financing should be found for nuclear power plants.

Activities like launching a project feasibility study, or setting up regulatory and project organisations and staffing them, are associated with significant financial commitments and therefore represent an important decision by the government and the organisations involved.

It is obvious that each of these decisions has to be carefully made and they should be based on the information, generated by an integrated planning process.

4.2. Organisation for co-ordination

The organisational requirements for co-ordination and co-operation could in principle be met by a classical project organisation of the matrix type, in which one co-ordinating and managing office is given access to other units in existing organisations to carry out work within their specialisation. In this case there will be a need to draw on many units, including several ministries (e.g. foreign affairs, finance, industry, energy, education and environment), electric utility, atomic energy authority, R&D institutes, industry associations, industrial standards institutes, etc.). It obviously will not be easy to co-ordinate this if it is not done by a high level office.

One way to achieve co-ordination could be through the establishment of a high level steering committee (Table III). The chairmanship would need to be at an appropriate level. Such a committee would require a commitment to active participation by all concerned. The government's commitment to the programme and planning process could at this stage be shown by its willingness to give a clear mandate to the steering committee, to make key personnel available from the relevant institutions and to assure financial support for the programme.

Somewhere there should be a "co-ordinating office" which is responsible for day to day follow-up and co-ordination. This could be located with the future plant owner. A clear designation of the co-ordinating office responsibilities and functions is necessary (see Table IV). It must have easy and direct contacts with all other units involved in preparations and plans, without bureaucratic restraints. If a steering committee is set up, the co-ordinating office could serve as the secretariat of that committee. The head of the co-ordinating office should have a high level of cognitive and managerial competence.

Table IV. Functions of Co-ordinating Office.

- Maintain listings of all activities with task specifications;
- Maintain direct contacts with all units involved;
- Maintain liaison with regulatory authority or the organisation which carries out the regulatory function;
- Develop a master schedule;
- Follow-up of work in all units;
- Co-ordinate special functions, such as manpower development;
- Prepare overall progress reports;
- Prepare decisions to be made by the steering committee;
- Maintain records of activities and decisions;
- Prepare summary reports, such as "white papers";
- Serve as secretariat of the steering committee.

As shown in Table II there is a large number of activities to be carried out. It will be necessary to define which organisation should be responsible for each action. This will depend on the existing structures in the country and no standard solution can be proposed. It is of vital importance that each unit has qualified staff to carry out the work. This will mean that the staff must have knowledge about nuclear matters, but in most units there will be some lack of specific expertise. In the early stages, it thus will be desirable to launch training programmes in the form of seminars with domestic and foreign experts, visits to other countries which have gone through the process successfully, using fellowships abroad for longer periods and establishing co-operation with appropriate organisations abroad.

In view of the central importance that manpower development will have, it would be very useful to set up a special unit — preferably within the co-ordinating office — which is responsible for assessing manpower availability, collecting manpower development needs and co-ordinating an overall manpower development programme [20]. As early as possible, training needs and necessary measures should be identified.

4.3. Scheduling

It would seem desirable to set up an overall time sequence for the planning work. It would not be so important that this schedule shows precise time deadlines, but it should have milestones showing in which situations important decisions have to be taken and the activities which have to be concluded before decisions can be taken. It should thus show the interrelationship of actions. If carried out in a strict manner, this would lead to a project management network plan that may involve some hundreds of activities.

Making such a network plan may be too complicated at the early programme planning stage, since deadlines and delays often will be imposed from the outside and will require both flexibility and ingenuity in the planning work. It is nonetheless necessary for the co-ordinating office to maintain a total overview of on-going activities in different places, with deadlines for their conclusion.

4.4. Assistance from outside the country

A main problem usually faced is the lack of national experience with planning such a complex programme, which probably has had no equal in past development programming in the country. Foreign assistance might be needed and should be utilized with caution so that commitments are not made prematurely.

The following are significant examples of non-recurring and well-defined tasks needing special skills that might need assistance:

- evaluation of grid-plant interaction;
- assessment of the needs for strengthening of the grid;
- possibility of grid interconnection;
- site survey and evaluation, leading to preparation of a list of possible sites (both for nuclear power plants and waste repositories);
- review of nuclear power plant designs;
- assessment of national industry.

Finally, at the end of the planning process, a consulting firm may be contracted to perform the feasibility study, which is a major undertaking. Use of a well-known consulting firm is a requirement in this case, since the study results will be used in support of requests for financing the project.

For each of these studies, it will be necessary for the planning organisation to:

- define the task in detail in a bid specification before awarding the contract;
- monitor the execution of the work; and
- review the report submitted by the consultants.

The work of the consultants should, of course, be used to train local staff so that more national expertise is available the next time the task has to be performed. The importance of developing national expertise needs no emphasis, as it is essential to assess and absorb such external work and advice. It is to be stressed that the responsibility arising out of decisions based on external advice lies with the owner.

Bilateral agreements are likely to be an important source of assistance to a country in the early stages of a nuclear power programme and such assistance should increase in importance as the nuclear power programme develops and becomes more concrete. Thus, it should be planned carefully from the beginning. Bilateral assistance and co-operation can be obtained at several levels:

- intergovernmental, between government ministries or authorities, including regulatory authorities;
- between utilities and power plant operators and their national organisations, such as EPRI (Electric Power Research Institute in the USA), WANO (World Association of Nuclear Operators) and INPO (Institute of Nuclear Operations);
- between nuclear research organisations;
- between industries and industrial organisations.

Bilateral assistance often can be obtained cost-free or on concessional terms, at least from government organisations, which can be of fundamental importance in building up a regulatory authority. For nuclear power, a close co-operation between plant owners, i.e. between utilities, often can be most valuable and should start early in the planning process so that confidence and trust develops between the organisations and individuals in them. Once a project has been launched there are a number of "owners groups" which make experience with a specific plant type or even major components (steam generators) available to its members. In the planning stage, it may not be fully clear how a co-operation can be established but utility organisations in supplier states can help to define useful mechanisms.

Many countries have bilateral, intergovernmental co-operation, assistance and supply agreements functioning in the research and development sector. These can be expanded to serve as a basis for co-operation and assistance programmes for nuclear power. For co-operation between plant owners, an intergovernmental agreement may not be strictly necessary, but it must be recognised that, if restrictions are imposed by the government, e.g. on bilateral trade, they may also affect information transfer and training in nuclear power. But this training can also be independent from the plant type, e.g. for development of safety culture, quality assurance, use of operating procedures.

Bilateral assistance schemes may be used in a more general way than through consulting firms, in giving advice for key functions in the overall planning work. A potential disadvantage is that the advisors may have experience only in the context of their own country's nuclear power development programmes.

Bilaterally sponsored training programmes have played a major role in the past. In the planning phase they can be especially useful for developing manpower for the regulatory and other government functions. For the plant owner's staff, bilateral training programmes have been most significant at the stage when a commitment has been made to a specific plant vendor but, as indicated, they can function also in the early stages. In planning the first NPP with foreign assistance, provision should be retained for training of personnel in a similar plant in the supplier’s country. This first batch of personnel trained abroad can become the core group who in turn can train others. This approach also provides valuable hands on experience.

The information requirements given in Appendix 1 could be used as a checklist for initiating programme planning.

A "high-level" seminar could be organized for the decision makers in the country, to provide information on some of the topics listed in Table V. It is an important opportunity to meet with all concerned decision-makers in order to provide them the relevant information and to discuss potential problems. The seminar must, therefore, be carefully planned with presentations by leading personalities in nuclear power programmes in other developed and developing countries, on their experience.

Table V. List of possible topics for seminar

- Status of nuclear power in the world
- Review of nuclear power programmes in developing countries
- Independence on energy supply/energy security
- Economic comparisons
- Operating experience with nuclear power plants
- Emissions and environmental and health impacts from different energy sources
- Organisational structures for planning, project management and execution, and plant operation
- Infrastructure assessment and development
- Quality management/quality assurance
- Manpower requirements and development
- Fuel cycle and back end options
- Options for waste management and disposal, including spent nuclear fuel
- Nuclear plant decommissioning
- Radiological risks and radiation protection
- Nuclear safety (safety culture, site safety, etc.)
- IAEA and international safety standards
- Setting targets for national participation
- Nuclear regulatory regime
- Sources of international assistance
- Financing
- International agreements
- Non-proliferation regime, safeguards, physical protection
- Site survey and evaluation
- Public acceptance problems and public information programmes.

5. ISSUES NEEDING POLICY DECISIONS

5.1. Policy decisions

Towards the end of stage C, i.e. "Developing the Nuclear Power Option", a point is reached where the decision on the nuclear power option has to be taken. Before establishing the nuclear power option in stage D, decisions should be taken on the policies regarding various aspects of the nuclear power sector listed in Section 3.4.1. This Section contains information on the most relevant issues that will enable arriving at a decision best suited to the country's interests. These issues are more extensively discussed in Reference [1].

5.2. Government/national commitment to a nuclear power programme

Experience in various countries, having launched a nuclear power programme, has shown that a strong commitment of the government/nation to the nuclear power programme is very essential for its success [3]. An organisational structure to promote and regulate the nuclear power programme is to be set up. Legislation towards promotion, regulation and nuclear liability are to be put in place. There is also a need to introduce appropriate curricula in the educational system and create the required training infrastructure towards nuclear power. Public perception of nuclear power is an issue, which has a political dimension. Setting up of NPPs requires international co-operation, which has to be done through the government. Apart from these, the government is also required to finance the programme in varying degrees, depending upon the situation and policies of the country. Several national agencies will be associated in the launching of the programme and their roles, responsibilities and actions have to be delineated, co-ordinated and monitored. A nuclear power programme has to be committed on a long-term basis and, therefore, continuity and stability in policies relating to the programme will be required. It is essential that there should be strongly committed organisations and leadership to implement and guide the programme, as interruption in programme and project implementation would lead to longer plant construction times and much higher costs. In view of all the above factors, for the programme success, there has to be a strong commitment, both governmental and national, for launching it. Such a commitment has to be followed by an "Action Plan" specifying actions to be taken, responsible agencies and time frame in which the actions are to be completed. This is essential to achieve an integrated approach to nuclear power programme planning.

5.3. Legal and regulatory framework development

The responsibility for the development of all the necessary structures to promote, regulate and maintain a nuclear power programme rests with the government and different national organisations and institutions in the country. There are legal requirements, at the national and international levels, which the establishment of a nuclear power programme will entail. Consequently, special legislation [1, 6] dealing with the nuclear facilities and related matters are of primary importance and should basically be aimed at:

— providing legislative authority for regulating and ensuring the safe development and use of nuclear energy in the national interests;
— vesting a specialised body with such a functional status and powers that would enable it to discharge its regulatory responsibilities independently of public/private corporations, manufacturers, suppliers;

— setting forth the principles and conditions under which the regulatory authority may authorise the carrying out of nuclear activities without undue risk to the workers and the health and safety of the public, with adequate physical protection of nuclear materials and facilities, with proper regard to protecting the environment and in accordance with international obligations entered into by the state; and
— establishing the principles and rules consistent with international conventions on third party nuclear liability for nuclear accidents.

Major components of the nuclear legislation should deal with the following aspects:

— Radiological protection, nuclear safety and connected matters such as environmental protection, transport of radioactive materials, radioactive waste management;
— Licensing authority and licensing requirements for activities involving nuclear facilities;
— Liability for third parties for nuclear damage and financial security for covering such liability;
— Physical protection of nuclear materials and facilities; and
— State system of accounting for and control of nuclear materials.

The responsibility for the safety of nuclear installations and for radiation protection must be defined by law, as the responsibility of the nuclear power plant operator and the role of the regulatory authority (or authorities, if radiation protection and nuclear safety have been allotted to separate regulatory bodies). The responsibilities of the regulatory bodies in establishing regulations, licensing and verifying that requirements are met, should be defined and these bodies should be given the necessary resources to carry out these tasks. The standards of the IAEA require that the regulatory authority be clearly separated from the operating organisations. However, in many countries both functions have been vested with the atomic energy authority, but even where this has been the case, there is now a clear trend towards ensuring that they are effectively separate.

Liability for nuclear damage is part of the legal framework that has developed around the peaceful uses of nuclear energy. The present international liability regime is embodied primarily in two instruments: the Vienna Convention on Civil Liability for Nuclear Damage (1963) and the Paris Convention on Third Party Liability in the Field of Nuclear Energy (1960); these are linked by a Joint Protocol adopted in 1988. The Paris Convention was later extended by the 1963 Brussels Supplementary Convention (see also Section 5.9).

Since the first international transfer of nuclear fuel, equipment and technology, assurances of exclusively peaceful uses have generally been a condition for supplies under bilateral agreements between a recipient and a supplier state. These agreements generally permitted verification by the authorities of the supplier state. Since the early 1960s, this verification of specific supplies has been in most cases delegated to the IAEA through its safeguards system, a function, which had been foreseen in its Statute.

5.4. Nuclear and radiation safety regime development

5.4.1. Nuclear regulatory regime

One of the possible alternative bases for regulation of the first nuclear power project, which has been adopted by several countries, has been to accept the regulatory requirements [1, 6] of the country supplying the nuclear power reactor. This has the advantage of gaining experience with a proven regulatory system as quickly as possible, but has the disadvantage that another set of regulatory requirements could be needed if the next plant would come from another country. An alternative, accepted by some countries, is to use the IAEA's Nuclear Safety Series (NUSS) of safety codes on siting [28], design [30], operation [18] and quality assurance [22] as basic regulations. The regulatory authority could be set up in conformance with the NUSS code on governmental organisation [26]. This would have the advantage of creating a common, internationally accepted base within which future differing approaches, if any, can be accommodated.

One basic requirement is that the regulatory organisation must have a high degree of independence in order not to be influenced, or be so seen by the public, by any considerations other than safety and to be able to report directly to the highest authority in the country. The question often raised is whether this would require the regulatory organisation to be within a Ministry other than the one to which the plant owner belongs. This would generally be desirable, but there are examples of regulatory organisations within the same Ministry as the plant owner that have operated very well, since they were given the necessary degree of independence and the possibility of reporting directly to the country's government. The power, effectiveness and authority of the regulatory body should be defined by laws. The level of safety concerns in the country will influence such arrangements.

The existence of a competent regulatory body, of course, in no way detracts from the fact that the primary responsibility for safety against accidents remains with the plant owner. The regulatory body has to specify which regulations and standards have to be used and it has to exercise surveillance to ensure that they are being met at all stages. It has to review the safety reports and other relevant documents relating to the plant and issue licenses, often separate licenses for the site, plant construction and plant operation. It however does not mean that the regulatory body takes actual responsibility for the safety of the plant; this responsibility rests fully with the plant owner.

5.4.2. Nuclear safety

An NPP is allowed to operate if, and only if, adequate measures to prevent accidents are in place. Nevertheless, if an accident does occur, it is necessary to be able to manage the accident to limit its escalation. At the same time, provisions are to be built in to mitigate the consequences, particularly with regard to the release of radioactive materials, so as to reduce the potential exposure of the public and plant personnel. Therefore, the low probability of accidents with potentially severe consequences has to be demonstrated through safety assessments, safety research, sound design with suitable materials, high quality construction, good operating practices and procedures, proper staff selection and training, etc. Appropriate reviews and assessments have to be carried out by the regulatory body. Because of this, there is a need for nuclear safety procedures to be established in all countries that set up and operate nuclear power plants and to be codified in laws, regulations and standards [1, 6]. Many IAEA Member States have already shown their commitment to this idea by consenting to be bound by the Convention on Nuclear Safety, which entered into force in October 1996.

In the NPP designs there is a general strategy of defence-in-depth for all technical safety measures. The defence-in-depth concept is centred on several levels of protection, including successive barriers to prevent the release of radioactive materials to the environment. This strategy is generally structured in five levels. Achieving the highest levels of quality in all stages of setting up a nuclear power project, by a structured quality assurance (QA) programme, is an overriding principle to be followed. The QA approach is part of an all-embracing safety culture of the organisation. In addition, safety culture needs to be bred and continuously enhanced, to create among the organisation's personnel an embedded sense of safety relevance.

5.4.3. Radiation protection

Ionising radiation and radioactive substances are natural and permanent features of the environment, and low level radiation is part of our surroundings. Exposure to radiation has an associated health risk and hence needs to be minimised to acceptable levels [1, 6]. Through the use of nuclear reactors for power production as well as for research, the amounts of radioactive materials available for medical and industrial use have been greatly increased. Radioactive materials control and radiation protection standards have been formulated and experience has shown that risks can be kept under control.

The International Commission on Radiological Protection (ICRP) has worked, since 1929, on the establishment of scientific principles for radiation protection. The basic recommendations of ICRP are kept under continuous review. The International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources (BSS), issued by the IAEA in co-operation with the Food and Agriculture Organization of the United Nations (FAO), the International Labour Organisation (ILO), the Pan American Health Organization (PAHO) and the World Health Organization (WHO), constitute a translation of ICRP recommendations into practical standards of radiation protection for the public and radiation workers. The BSS have been updated several times in response to changed ICRP recommendations, most recently in 1996 [31]. It is well known that nuclear industry from the early stages of its development has grown with the special emphasis on strict adherence to these standards.

5.5. Manpower development

The availability of sufficient number of qualified manpower at the time when they are needed is one of the essential requirements [20]. Specialised knowledge and excellence in human performance is required in all the phases of the programme. Manpower requirements by way of numbers, education, experience and training must be established for the programme as a whole. Manpower requirements encompass project-oriented activities such as pre-project activities, project implementation, manufacture of equipment and components, plant construction, plant commissioning, plant operation and maintenance. It should also contain programme oriented supporting activities such as nuclear power programme planning, nuclear fuel cycle activities, nuclear licensing and regulation, research and development, and education and training. The manpower requirements and development are not only confined to the organisation responsible for implementing the nuclear power programme but also to other organisations in the nation connected with the nuclear power programme. For instance, the programme will pose a demand for manpower in the national infrastructure of the country e.g. government, industry, science and technology institutions, education and training institutions. These are also to be defined.

The manpower requirements will depend on:

— the scope and schedule of the programme;
— the scope and schedule of national participation in the programme;

— the constraints and limitations on the scope and schedule imposed by national industrial, educational and technological infrastructures and manpower resources; and
— national conditions and characteristics affecting the labour market such as productivity, efficiency, competition from other industries, employment policies, labour costs, customs, rules, and legislation.

Manpower loading curves based on different categories and timing of requirement are to be prepared for the programme to assess the magnitude of the task. The manpower requirements are in three levels i.e. professionals, technicians and craftsmen. The numbers will vary from country to country and they will be country specific.

After assessing the needs, a manpower development programme will have to be launched and actions are to be taken at the national level. Educational and training institutions may suffer from insufficient support from the government and local agencies. Some of the actions for development of the infrastructure are modification and up-gradation of the existing educational and training infrastructure at schools, universities, technician and craftsmen level educational institutions, to meet the needs of the nuclear power programme. This has to be launched on a national basis. Apart from the manpower development angle, this is also convenient from the consideration of public education on nuclear energy.

The institution responsible for implementing the nuclear power programme should set up its own specialised training facilities at the induction stage of the manpower. Training for operation and maintenance needs must be given initial priority. The infrastructure for qualifying and licensing the personnel will have to be developed. Initially the approach of foreign training of the manpower at the supplier's country in a similar power plant could be adopted. The core people so trained can act as trainers of further batches and develop more manpower.

Manpower development requires considerable efforts and actions have to be initiated well ahead in the early stages of the programme. It requires attention at the highest level of management. It also requires actions at the national level for modification, up-gradation and setting up of the required educational and training infrastructure. The manpower sources have to be a combination of experienced personnel from industry and fresh candidates from universities, and professional institutions for technicians and craftsmen, who could be put through specific training programmes to meet the needs of the nuclear power programme.

5.6. National participation in nuclear power plant projects

One policy to be developed during the last two stages of planning for the development and establishment of the nuclear power option concerns the desirable extent of national industrial participation in the first and subsequent projects [1]. This activity best starts in stage B 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 possible nuclear power programme. The first nuclear project has usually been 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 should 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.

The IAEA has published guidelines on how the domestic industrial support can be used and developed [7]. A suggested minimum level of domestic participation by all organisations involved is outlined in Table VI. This minimum level is demanding on the country even though outside help can be used for a number of functions. The demands are placed primarily on the regulatory and plant owner organisations and represent functions they have to carry out. It should be recognised that it is not possible to delegate any of the regulatory body functions to foreign organisation or separate specialists. The regulatory body could use consulting services from abroad, but it must perform all regulatory functions by its own resources. It is assumed that the plant owner will contract for considerable outside assistance. For the national industries, the minimum level involves participation in the civil construction works and in delivering construction materials. Any additional use of the national industry should be evaluated very carefully, especially in regard to the industry's ability to meet QA standards.

Table VI. Minimum national participation

Regulatory authority:	• Establish regulations and standards • Safety reviews • Licensing procedure • Inspection and surveillance • Enforcement
Plant owner:	• Planning activities • Feasibility study • Contracting • Safety reports development • Owner's project management • QA surveillance • Plant operation and maintenance
Industry:	• Construction materials • Civil construction work

A new type of contracting and financing for thermal power plants has appeared, which requires far less domestic involvement, viz. build-operate-transfer (BOT) or build-own-operate (BOO). Under both of these contract types a foreign contractor, usually a consortium, would finance and construct the plant. The BOT and BOO contracts differ with regard to the operation of the plant. Under the BOT form, the consortium would operate the plant for a specified number of years, until the investment and interest/return on investment has been repaid, and then transfer it to a local owner, whereas under the BOO form the consortium would operate the plant for its entire lifetime. Both contracting types have the objective of alleviating national financing constraints by involving foreign and local private investors in the consortium. These models have so far not been tried for an NPP, but initial discussions for such a contract have been conducted in some countries. There is an obvious formal difficulty due to the plant owner's responsibility for safety and liability for accidents, which should have been established in national law, and also in the relationship between a foreign plant owner and the domestic regulatory authority. It is unlikely that a BOT or BOO arrangement for an NPP can be made along exactly the same lines as for a thermal power plant, which might require no government involvement. Such arrangements for an NPP are likely to require a joint venture type of concept, in which the government would be involved together with foreign partners, as was the case with Daya Bay in China. These developments should be watched carefully, since they could provide relief from many infrastructure development requirements in a country where a decision has been taken that the availability of electricity is more important than the transfer of technology.

5.7. Environmental aspects

Environmental and other impacts of different energy options should be included in nuclear power programme planning. The Helsinki Symposium on Electricity and the Environment in 1991 [14] pointed out that there is still a lack of generation system planning methodologies which incorporate environmental and health impacts, and that including the impacts in decision making in a rational manner represents a constraint, even in industrialised countries. Environmental impact analyses often are required and made for any large project; however, they clearly are of no help in the programme planning work, since they are made as a part of the preparations for a specific project. In the case of NPPs, at least the specific aspects of possible radiation impacts are included in the preliminary safety analysis report. What is needed are tools for comparative environmental and health impact assessments of different energy and electricity strategies.

Since the early 1970s, the IAEA has been engaged in developing methodologies and computerised software packages for planning the expansion of national energy and electricity systems with due consideration to the possible role of nuclear power including a methodology, software and databases for comparative assessment of the full energy chains of different electricity generation options, with due consideration of technical, economic, environmental and human health impacts (see Appendix 2 for a brief description of these models).

There are regional and international, transboundary effects of energy systems resulting from the emissions of SO_2 and NO_x, which give rise to acid rain, and of CO_2, which is of concern, due to its potential risk to affect the global climate. As a consequence, there is now a far-reaching agreement on targets for reduction of SO_2 and stabilisation of NO_x emissions in Europe where the impacts have been particularly serious. The agreement is documented in a regional treaty, which is reflected in national regulations, limiting emissions. There also is progress on an international treaty aimed at limiting CO_2 emissions globally to levels where they would not have adverse effects on global climate; however, agreement on the quantification of emission limits for CO_2 probably will take many years to achieve. Although there are no significant transboundary effects of acid rain in developing countries, national regulations may be established to limit emissions in view of reducing local or regional impacts within a country and these would, of course, have to be taken into account in the planning work. The Conference of the Parties to the Framework Convention on Climate

Change (Kyoto) established international commitments to reduce greenhouse gas emissions by 2008–2012. A large portion of the Kyoto reduction targets might be achieved through improved efficiency in energy use or through other means, such as the "clean development mechanism", but, in order to meet the remaining of the reduction, some current energy resources would have to shift from fossil to non fossil-fuel sources. It might be useful to note that the economic benefits of nuclear programmes are closely related to the costs of reducing carbon emissions as specified in the Kyoto protocol. Greater levels of carbon emission reductions give rise to ever increasing costs of competing fossil-fuelled technologies, thus making the nuclear power option increasingly more attractive. The declaration made at the Earth Summit at Rio in 1992 paved the foundation for the development of the Environmental Management System (EMS) through ISO-14000 which is a series of several international standards developed by the International Organisation for Standardisation (ISO). This further strengthens the principle and need for sustainable development and environmental protection.

5.8. Financing

There are three main characteristics of nuclear power projects, which make financing difficult [1–3]:

- the high investment costs which may even exceed the overall credit limits of lending institutions for an individual developing country;
- the longer construction time than for fossil fuelled power plants;
- the potential uncertainties in schedule and costs due, for instance, to regulatory and public intervention, long construction duration and policy changes.

Innovative financing models like BOT (build-operate-transfer) or BOO (build-own-operate) are now being used in some cases for fossil fuelled thermal power plants. A few attempts have been made to use them for nuclear power plants but they have not been successful.

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. For example, the nuclear power plant at Daya Bay in China was financed through the formation of a joint venture with participants from China and Hong Kong.

It may well be that the government could find itself having to make a choice between available credits being used for an 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 (see Table VII).

An overriding consideration for the lending institutions will be the creditworthiness of the country and the plant owner. This will depend 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.

Table VII. Financing factors

- Is the nuclear power 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 nuclear plants supportable or are there sources, which would be more acceptable?
- Is the currency risk covered?
- Is there a government guarantee?
- Can new and more innovative financing models like BOT or BOO be used?
- Do electricity tariffs reflect full cost recovery in a deregulated market?[2]
- 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?

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 before any policy decisions on a nuclear power programme 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 nuclear power option is included in the planning process. It will require using a group having expertise to deal with financial, economic and legal questions.

5.9. International treaties and agreements

As mentioned before, a number of international agreements will be needed in order to use the international market for nuclear power plant equipment, supply of fuel and fuel cycle services, and transfer of supporting technology. Supplies of nuclear materials and equipment have for a long time been subject to IAEA safeguards to assure exclusively peaceful uses. Most supplier states have, in addition, agreed to make adherence to the Non-Proliferation Treaty (NPT), or a similar comprehensive treaty with guarantees against proliferation, a condition for supplies. This will also require that the recipient country concludes a safeguards agreement with the IAEA covering all present and future nuclear activities in the country. In addition, supplier countries will normally insist on a framework bilateral agreement covering materials and supplied technology. There are also a number of additional treaties, which may give benefits to the country or increase its credibility and which should be considered (Table VIII). Some of the main treaties, especially NPT, probably may have already been accepted by the country, but negotiating the supplementary and bilateral agreements will require considerable effort, most often led by the foreign affairs ministry, with support from the future plant owner and other nuclear specialised organisations.

[2] It is essential to cover full cost of production and that there should be no subsidies.

Table VIII. International Agreements and Treaties

- NPT or regional treaty, such as Tlatelolco.
- Safeguards agreement with IAEA.
- Bilateral co-operation and supply agreement(s).
- Nuclear liability convention — Paris, Vienna. (Can serve as foundation for national liability law).
- Convention on Early Notification of a Nuclear Accident.
- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.
- Convention on Physical Protection of Nuclear Material.
- Convention on Nuclear Safety.
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

5.10. Nuclear fuel cycle

The nuclear fuel cycle [1, 2, 25] 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 nuclear power plant, and the back end, which includes the activities concerning the spent fuel.

The acquisition by a country of its first NPP might involve a major degree of dependence on external suppliers, with associated commitments to non-proliferation and international co-operation. The power plant 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 or more years.

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

— Reprocessing of spent fuel and recycling of plutonium in reactors (for example, fabrication of MOX fuel to be recycled in LWRs);
— Storage for 30–50 years and subsequent disposal as high level waste (HLW) (the once-through cycle);
— Deferral of the decision on whether to reprocess or dispose of the spent fuel.

Development of a national industry for the activities of the full nuclear fuel cycle is expensive and should only be considered if the size of the nuclear power programme does justify its economic viability. In this context, it is possible that a few countries in a region may enter into regional co-operation agreements to make the nuclear power option more viable and competitive.

5.11. Radioactive waste management

Radioactive waste has become the focus of some environmental concerns in connection with nuclear power [1]. The main feature of wastes from nuclear power plants is that they arise in small quantities, which therefore can be readily managed and disposed of. Radioactive wastes are divided into the following three categories:

- Low level waste arising from nuclear power plants which has to be kept isolated only for limited periods of time and does not usually require special handling.
- Intermediate level waste consisting to a great extent operational wastes from power plants such as ion exchange resins, which require shielding to protect the workforce.
- High level waste consisting of fission products and plutonium contained in the spent fuel, which has to be safely isolated from the environment for very long periods, possibly hundreds of thousands of years. High level waste also generates heat, which can be significant for the first 30–50 years. The quantity of this waste per unit of energy produced is very low, of the order of about 0.5 cm^3/MW·h in an LWR [32].

The objective of safe waste management involves the application of technology to limit the exposure of the public and workers to ionising radiation and to protect the environment from release of radioactivity in accordance with national regulations and internationally agreed standards.

Operational radioactive waste, both low level and intermediate level, from NPPs is often treated (to reduce its volume) and/or conditioned (immobilised, i.e. converted to a mechanically stable and insoluble form and packed) prior to disposal. Several effective, safe and feasible treatment and conditioning options exist for these types of wastes. Management of these wastes have been established and proven over the past forty years. Well proven technology is also available for disposal i.e. shallow land burial in concrete lined trenches or disposal on the structures on the ground surface, or subsurface disposal. Countries are continuing to rely on a combination of near surface and sub surface facilities for disposal.

The high level waste arises from the spent fuel. Two general approaches are possible for management of spent fuel:

- Reprocessing, in which the spent fuel is processed to isolate plutonium and uranium for recycle, also produces a residue of fission products and actinides known as high level waste
- Direct disposal, in which the conditioned spent fuel itself, is disposed of as waste after a period of storage.

The strategy in choosing between the above two options depends on economic, political and energy policy considerations. Regardless of which strategy is adopted, the spent fuel or high level waste must be appropriately conditioned, transported to a disposal site and disposed of therein. Methods for immobilising high level wastes are also available. With regard to permanent disposal of high level waste there is a broad agreement among scientific organisations around the world that deep geological disposal is a suitable method for permanently isolating the radioactive waste from the environment. Much development work has been done in this area. There are many geologically suitable sites for repositories for permanent disposal. However, the issues of public acceptance are to be solved. The safety of deep geological disposal is achieved by use of multiple barriers. Repositories are typically planned to be constructed at a depth of several hundred to one thousand metres in media such as granite or other crystalline rocks, bedded or domed salt formations, argillaceous deposits (e.g. clay or shale), or volcanic deposits (e.g. basalt or welded stuff). Several countries plan to operate deep geological repositories for disposal of their spent fuel and high level waste in the next twenty to thirty years. Currently there is no final repository for high level waste in operation but the technology that can be used is well studied. The problem could be more easily solved through international co-operative ventures for the back end of the fuel cycle involving intermediate storage of fuel, possible reprocessing and MOX fuel fabrication where desirable, and disposal of high level waste. However, there is now a general international position that each country should take care of its own radioactive wastes.

5.12. Decommissioning

At the end of its useful life, a nuclear power plant has to be decommissioned [1]. A useful life of 30 years is often referred to, but nuclear power plants are usually designed for 40 years of operation. The lifetime could be extended beyond 40 years with suitable management programmes that include control of degradation processes, maintenance, repair and refurbishing and/or replacement of plant components and systems.

There are essentially two options for the process of decommissioning a nuclear power plant:

(a) The plant is dismantled soon after operation ceases and the site is restored or adapted for reuse;

(b) Fuel is discharged to a storage facility and non-radioactive parts of the plant are dismantled but the radioactive parts are mothballed for 30–50 years or even longer before dismantling.

The first option has the benefit of making potentially valuable sites available for other purposes, notably for new power plant units, as early as possible. It would also remove the problem of continuing public concern about whether the reactor remained a threat to public health and safety.

The second option has the benefit of reducing the total radiation dose to decommissioning workers as radioactivity will have decayed substantially in the 30–50 year mothball period. This would also reduce the cost of dismantling, though the saving may be partly or completely offset by the cost of maintenance and surveillance — during the mothball period. Technology is available for dismantling radioactive reactors today. New technology is foreseen that would allow further reduction of costs and worker exposure.

In both cases, as a result of dismantling some radioactive materials will have to be managed as waste. The fuel will in either case be discharged at an early stage and managed according to the option selected for the back end of the fuel cycle. The primary circuit will have radioactive components with a fairly rapid decay which can be treated as LLW or ILW, at least after a few years or after decontamination. Some of these components are large but are easy to handle or can be cut into smaller pieces. Only a small part of the plant is radioactive. Most of the plant never becomes radioactive and therefore presents no particular problems for immediate dismantling and possible reuse of the equipment. The costs of decommissioning NPPs including disposal of associated wastes are small and 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.

5.13. Public acceptance

Public acceptance [1] is a very important issue for nuclear power. As mentioned in Section 3.3.2, the justification of the nuclear power option during the stage B must 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. However, attitudes vary from country to country. In some countries there is acceptance of nuclear power. In other countries, both industrialised and developing, public opinion has turned against nuclear power and this is often cited as a major obstacle to its further development. The argument used against nuclear power option focuses on three issues:

- The risk of repetition of a serious reactor accident with consequences like those of Chernobyl accident
- The claim that waste presents a problem that has no solution
- The alleged close link between civilian nuclear power and nuclear weapons.

A lot of factual information is available on the above subjects to allay the perceived fears. The experience has shown that the only way to influence public opinion is through a carefully designed long-term information programme based on correct and neutral information. Such a programme requires a major effort but its importance should not be under estimated. The information strategy should define the goals, messages to be delivered, key target audience, method of communication, and existing assets that can be drawn upon. The strategy should also include teaching about energy and electricity including nuclear energy in schools, universities, information centres, a strong media relationship programme, a separate information programme for legislators and politicians. Information programme should present benefits from a nuclear power programme as well as risks in a balanced manner to bring in that the benefits outweigh the risks and there are adequate provisions to mitigate the perceived risks. Public participation in decision making is also another tool towards confidence building.

5.14. Other national policies

National governments will probably have laid down policies in such sectors as national development (including goals and priorities), energy development (including supply), environment and international relations. These could be in the areas of energy security, development of indigenous resources, economic optimization of energy and electricity supply, environmental considerations, deregulation of energy/electricity market. In addition foreign policy and external relations, regional issues, are other relevant areas. These policies would be of a long-term nature and where they are the result of consensus they would not be expected to change with political changes in the country. In some countries energy policy has become an issue of party politics instead of national policy, which has made it difficult to formulate long-term energy plans. In these circumstances, a nuclear power programme, in particular, has become almost impossible to pursue. Therefore, it is necessary to have a national consensus for the success of the programme. Nuclear power policy issues cannot be addressed without consideration of how national policies on energy, development and international relations may influence nuclear power development and operation.

6. SUMMARY

Demand for electricity is growing at a rapid rate, particularly in developing countries due to the relationship of electricity demand with the process of development. Quality of life of the population is linked to the per capita electricity consumption. Therefore, all forms of technically feasible, economically viable and environmentally sustainable sources of energy have to be exploited for electricity generation. Any electricity expansion planning process, whatever the primary energy sources are considered, should be based on the three main principles: economy, energy security, and impact on the environment [33]. It is in this context nuclear energy has a global role to play in future.

Nuclear power is a complex and demanding technology and the planning process leading up to a decision on a nuclear power programme is also complex and demanding and would benefit from a systematic and integrated approach. This has not always been recognised in the past, which may be a part of the reason for the slow pace of nuclear power programmes in different countries. There may have been other and more compelling reasons, but it can be argued that the planning process in itself can constitute a constraint if not properly approached and executed.

There are four stages from the conceptualisation of the project up to a well-founded decision to carry out a project and site feasibility study:

- Stage-A: Creating the basic competence in system analysis for planning;
- Stage-B: Examining the nuclear power option;
- Stage-C: Developing the nuclear power option;
- Stage-D: Establishing the nuclear power option.

There are several activities that are to be carried out by different agencies in the country. Decisions at each stage have specific significance and therefore require careful consideration of all the relevant factors.

After establishing the organisation capable of analysis for planning and taking into account the energy policy framework, a long-term economic electricity expansion plan is developed. This would result in including the nuclear power option in the planning framework. Thereafter, the option is examined from optimum electricity system expansion considerations, requirements of infrastructure and possible sources of assistance. This step leads to a decision to identify possible sites. The various policies relating to the nuclear power option are thereafter developed. The next stage is establishing the option by way of setting up a legal and institutional framework and creating the required organisations, negotiating international agreements, and ultimately launching a feasibility study.

In order to achieve an integrated approach, one way is that a national steering committee, with the help of a co-ordinating office, directs these activities. This will help in solving the problems and issues that may come up from time to time between the various agencies of the country. In parallel, the core project management team can develop and take over the functions once the decision on the nuclear power option is made and project feasibility study is undertaken.

The key aspects on the planning of the nuclear power programme are:

- Securing a strong government/national commitment;
- Putting in place the legislation for legal and regulatory framework;
- Establishing the base for regulating the setting up the first NPP;
- Setting up early actions at the national/organisational level on manpower development;
- Deciding on the optimum level of national participation;
- Assessing the environmental advantages of NPPs using the relevant energy planning models; and
- Establishing strategies for financing, external assistance, nuclear fuel cycle, radioactive waste management, decommissioning and public acceptance.

Authorities should take a careful look at the means available for planning a nuclear power programme, creating its organisational structure and establishing guidelines to approach the work. Assistance will be needed from several sources abroad and a good mixture should be set up. This should be supplemented by local expertise to absorb such assistance/advice.

The approach to integrated planning will differ from country to country due to a spectrum of situations prevailing in the different countries. Therefore, the approach cannot be generalised with specific prescription. However, this publication provides information on the outline of an integrated planning process for introducing nuclear power from the stage of conceptualisation to the stage of a decision to go for a feasibility study. Using this information, the integrated planning process has to find a solution that is best suited to each country's situation.

Appendix 1

INFORMATION REQUIREMENTS
CHECKLIST FOR INITIATING PROGRAMME PLANNING

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.
- CO_2 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, 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 FEASIBILITY STUDIES

(Sources: Country studies, IAEA studies, 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 feasibility 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.

- Law and regulations for radiation protection. Regulatory body.
- Law and regulations for safety of nuclear installations. Regulatory body.
- Compatibility of national radiation protection and nuclear safety regulations with IAEA codes and guides.

- Law and regulations for ownership of nuclear installations and materials. Considered necessary?
- Law or policy concerning nuclear third party liability.
- Party to NPT, Tlatelolco or Rarotonga? 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 organisations 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.

APPENDIX 2

SUMMARY OF IAEA METHODOLOGIES AND TOOLS FOR ENERGY, ELECTRICITY AND NUCLEAR POWER PLANNING AND COMPARATIVE ASSESSMENT OF ENERGY SOURCES

This addendum contains a brief description of the various computer tools related to electricity and nuclear power planning and to energy source assessment that have been developed by the IAEA, either on its own or with the help of other organizations, and disseminated to Member States. (Reorder sequence of tools according to Stages A and B)

Wien Automatic System Planning Package (WASP): The WASP model is a tool for carrying out power generation expansion planning studies. The model permits to analyze the economic competitiveness of nuclear power in comparison to other generation expansion alternatives for supplying electricity requirements for a country or region. The model provides the optimal expansion plan for the selected power generating system over a period of up to thirty years, within the constraints given by the planner. The optimum is evaluated in terms of minimum discounted total costs.

Model for Analysis of Energy Demand (MAED): This model was developed in 1981 to allow for the determination of electricity demand, consistent with the overall requirements for final energy in a country, and thus, to provide a more adequate forecast of electricity needs to be considered in the WASP study. MAED, in conjunction with WASP, has been widely used by the IAEA in the conduct of energy, electricity and nuclear power planning studies for Member States under the IAEA's Technical Co-operation Programme.

Energy and Power Evaluation Program (ENPEP): ENPEP is a set of PC-based analytical tools for integrated energy/electricity system planning and the quantification of environmental burdens. The ENPEP package is being applied in the conduct of Energy and Nuclear Power Planning Studies, as well as for Green House Gas (GHG) mitigation assessment. The BALANCE Module of ENPEP is used to trace the flow of energy throughout the entire energy system from resource extraction, through processing and conversion, to meet demands for useful energy (e.g. heating, transportation, electrical appliances) and to project future energy supply/demand balances. Results of the BALANCE analysis is then passed to the IMPACTS Module in order to calculate environmental burdens (e.g. air pollution, solid waste generation, and water pollution) associated with different scenarios of energy sector development.

VALORAGUA: This model was originally developed by Electricidade de Portugal (EDP) for planning the Portuguese power generating system. In 1992, the IAEA, in co-operation with EDP, developed a PC version VALORAGUA as an additional module for use in connection with the WASP methodology. The VALORAGUA model is helpful in the preparation of the hydro plant characteristics to be input in the WASP study and to verify that the WASP overall optimized expansion plan takes into account an optimization of the use of water for electricity generation. The model aims at determining the optimal operating strategy of a mixed hydro-thermal power system, taking into account the operating characteristics of the system and the stochastic nature of some of the variables involved (inflow energy to the reservoirs, forced outages of the power plants, etc.). The combined application of VALORAGUA and WASP permits the determination of the optimal expansion of combined thermal and hydro power systems, taking into account the optimal operation of hydro reservoirs throughout the year.

FINPLAN: This model was designed to evaluate the financial implications of implementing a power generation system expansion programme. In 1990, staff of the Bank Credit Lyonnais, Paris, France, developed the model under a contract with the IAEA. After determining the most economical power investment programme for a country, for example using WASP, FINPLAN could be used to determine the financial consequences of these investments. In addition, FINPLAN helps to establish the selling price of electricity which would permit payback, and automatically calculates annual changes in profits and losses. Forecasts developed with the model take into account price sensitivity to exchange rates, fluctuations or variations of demand, and foreseeable inflation rates for both domestic and foreign currencies. The model also integrates simplified taxation elements which include calculation of revenues accounting for interest rate deductions, past reported losses, possible amortization and proportional taxation rates.

BIDEVAL: The IAEA computer program package for economic bid evaluation Bideval-3 is a set of computer programs to assist the user in the process of economic evaluation of bids for nuclear power plants. The program follows the recommended method of determining the present value of all costs for capital investment, nuclear fuel, and operation and maintenance to obtain the levelized discounted electricity generation costs as described in the Bideval Guidebook [34].

DECADES Computer Tools: The development of the DECADES Computer Tools was initiated in 1993 within the joint inter-agency programme on Databases and Methodologies for Comparative Assessment of different Energy Sources for Electricity Generation (DECADES). These tools consist of databases and analytical software that can be utilized by a wide range of users at the national, regional and international levels to evaluate trade-offs between technical, economic and environmental aspects of different electricity generation technologies, chains and systems [35].

Two types of technology databases were developed to provide comprehensive, and up-to-date information on energy chains for electricity generation. The Reference Technology Database (RTDB) provides a comprehensive, harmonized set of technical, economic and environmental data on some 300 typical facilities covering energy chains that use fossil fuels, nuclear power, and renewable energy sources for electricity generation. Country Specific Databases (CSDBs) store data similar to those in RTDB but specific to various countries or regions for the purpose of carrying out case studies with the DECADES analytical software as well as other national planning tools. The CSDBs accommodate site-specific data, which are not stored in the RTDB. Some twenty-five countries have developed CSDBs, containing a total of more than 2,500 facilities.

The DECADES analytical software, called DECPAC, is designed to access information stored in the technology databases for analysis and comparison of costs and environmental burdens at the power plant, energy chain and electric system levels. Its design focuses on user friendliness, enhanced environmental analysis capabilities, extensive reporting capabilities, and short running time for optimizing electricity generation system expansion strategies over a period of several decades.

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ABBREVIATIONS

BOO	Build–own–operate
BOT	Build–operate–transfer
BSS	Basic Safety Standards (Ref. [31])
DECADES	Databases and Methodologies for Comparative Assessment of different Energy Sources for Electricity Generation
DEPAC	DECADES Package
EEDB	Energy and Economic Data Base
ENPEP	Energy and Power Evaluation Programme
EMS	Environment Management System
EPRI	Electric Power Research Institute
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
HLW	high level waste
ICRP	International Commission on Radiological Protection
ILO	International Labour Organisation
INPO	Institute of Nuclear Power Operations (USA)
LWR	light water reactors
MAED	Model for Analysis of Energy Demand
MOX	mixed oxide
NPT	Non-Proliferation Treaty
NUPAT	Nuclear Power Advisory Team
OECD	Organisation for Economic Co-operation and Development
PAHO	Pan American Health Organisation
R&D	research and development
TC	technical co-operation
VALORAGUA	Portuguese model for planning (hydro) power generating system
QA	quality assurance
QM	Quality management
UNDP	United Nations Development Programme
WANO	World Association of Nuclear Operators
WEC	World Energy Conference
WHO	World Health Organization

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