IAEA Nuclear Energy Series

No. NG-T-3.7

Basic Principles

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Managing Siting Activities for Nuclear Power Plants

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IAEA NUCLEAR ENERGY SERIES PUBLICATIONS

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MANAGING SITING ACTIVITIES FOR NUCLEAR POWER PLANTS

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

IAEA NUCLEAR ENERGY SERIES No. NG-T-3.7

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FOREWORD

One of the IAEA's statutory objectives is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world". One way this objective is achieved is through the publication of a range of technical series. Two of these are the IAEA Nuclear Energy Series and the IAEA Safety Standards Series.

According to Article III.A.6 of the IAEA Statute, the safety standards establish "standards of safety for protection of health and minimization of danger to life and property." The safety standards include the Safety Fundamentals, Safety Requirements and Safety Guides. These standards are written primarily in a regulatory style, and are binding on the IAEA for its own programmes. The principal users are the regulatory bodies in Member States and other national authorities.

The IAEA Nuclear Energy Series comprises reports designed to encourage and assist R&D on, and application of, nuclear energy for peaceful uses. This includes practical examples to be used by owners and operators of utilities in Member States, implementing organizations, academia, and government officials, among others. This information is presented in guides, reports on technology status and advances, and best practices for peaceful uses of nuclear energy based on inputs from international experts. The IAEA Nuclear Energy Series complements the IAEA Safety Standards Series.

The introduction of nuclear power brings new challenges to States — one of them being the selection of appropriates sites. It is a project that needs to begin early, be well managed, and deploy good communications with all stakeholders; including regulators. This is important, not just for those States introducing nuclear power for the first time, but for any State looking to build a new nuclear power plant.

The purpose of the siting activities goes beyond choosing a suitable site and acquiring a licence. A large part of the project is about producing and maintaining a validated, referenced bank of data that can be used during the lifetime of the nuclear power plant. As a result, and after reviewing the existing publications, the IAEA decided to develop an integrated Nuclear Energy Series publication on managing siting activities for a nuclear power plant using recent siting experience from States. This publication:

- Complements the IAEA Safety Guide related to site selection;
- Emphasizes the integrity and interdependence of various activities related to site selection and assessment, including safety, environmental, technical, economic and social factors;
- Develops the methodology and framework for all aspects of the siting process;
- Updates the existing IAEA documentation in order to better reflect the developments in the nuclear and energy industry related to siting;
- Integrates the existing IAEA publications on the subject into a more compact and user friendly guide.

This publication provides the information necessary to organize, guide and realize the activities related to the selection and assessment of a site through defining the factors for consideration and methodologies for site investigation. Other factors that could have an impact on the final selection, such as national or international politics are not addressed. This publication also discusses communication with and involvement of stakeholders as this has a strong influence on the process of selecting a site for a nuclear power plant.

This report is intended for use by Member States initiating, restarting or expanding their nuclear power programmes. It gives guidance on the complex organizational, engineering, socio-economic, and environmental issues of siting. It aims to enable States to develop detailed country-specific processes for implementation of siting activities or to improve the efficiency and effectiveness of the siting process.

This publication may be used by utilities assessing the possibilities for building and operating a nuclear power plant as well as by contractors in the nuclear power industry.

The IAEA officer responsible for this publication was V. Nkong-Njock of the Division of Nuclear Power.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

The IAEA supports the safe and peaceful use of nuclear power by providing standards, guidance, review and assessment, inspections and assistance related to:

— Technology;
— Safety and security;
— Safeguards.

The increased demands for assistance in developing and implementing well managed programmes for the introduction of nuclear power in new countries, led the IAEA to develop a publication in the Nuclear Energy Series entitled Milestones in the Development of a National Infrastructure for Nuclear Power [1]. This publication describes the detailed infrastructure needed to support the safe, reliable and peaceful use of nuclear power. It identifies 19 separate infrastructure issues to be addressed by a State that is considering the introduction of nuclear power. This publication addresses one of the identified infrastructure issues; the selection and evaluation of possible sites for a nuclear power plant.

The project to select the site for a NPP needs to begin early, be well managed and deploy good communications with all stakeholders, including regulators. It is widely recognized that when a State decides to begin or expand its nuclear power programme, the choice of the sites that will host the power plants is likely to be politically contentious. Evidence suggests that even in countries that rely on nuclear power for a large proportion of their electricity needs, there is a significant opposition to the nuclear industry and issues related to the site are often a source of conflict. It is therefore an important topic, not just for those States introducing nuclear power for the first time, but for any State looking to build a new nuclear power plant. Done well, it will ensure the right choice of site(s) taking into account safety, environmental, technical, economic and social factors and will allow the project to be completed within its programme. If not properly planned and executed, it is likely to result in major delays to a programme or even failure to complete the intended project.

It is therefore important to establish a comprehensive management system to support the planning and implementation of the siting activities, and to ensure that the required quality of the activities is achieved. It is also important to share good practices on these issues.

The IAEA has published Safety Standards No. NS-R-3, (2003) entitled Site Evaluation for Nuclear Installations: Safety Requirements [2]. This is complemented by a number of Safety Guides and related publications [3–6].

The present publication is being developed to complement these IAEA Safety Guides in order to provide guidance on siting issues related to management, technical, economic, environmental and social factors. Together they aim to provide consistent and complete guidance on siting.

1.2. OBJECTIVE

Together with the IAEA Safety Guides, the purpose of this publication is to help States ensure that appropriate sites for a nuclear power plant are identified, assessed and licensed, in a well-planned and efficient manner, taking into account all relevant factors. It is applicable to countries with existing nuclear facilities as well as those introducing a nuclear power programme.

For those countries introducing nuclear power for the first time, this publication provides a framework for managing siting activities within the development of a national infrastructure for nuclear power development.

The objectives of this publication are to accumulate and disseminate information and guidance that will help to:

— Identify and evaluate key issues that affect decisions on the suitability of a site for new nuclear power plants;
— Establish a management framework for the planning, control, implementation, verification and coordination of all the siting activities.

This publication will provide the methodology and framework to enable States to develop a detailed and specific national process to meet the needs of all aspects of the siting process. It is intended that the publication of this report will lead to improvements in the selection of the best sites, the implementation of siting activities, and the efficiency of the regulatory and stakeholder review process.

1.3. SCOPE AND STRUCTURE

This publication applies to the planning and implementation of siting activities within the lifecycle of the nuclear power plant, in countries with established nuclear power infrastructures as well as in States introducing their first nuclear power programme.

This publication focuses primarily on activities up until the requests for bidding for a particular site (i.e. Phase 1 and Phase 2 of a new nuclear power programme, see Sub-section 2.3) although the later activities are summarized. In order to prepare an appropriate bid invitation specification, the site selection and site assessment will need to be completed. The principles of managing siting activities and the relevant factors described in this report will continue to apply.

Section 2 explains the context of siting work within the overall programme of work to construct a nuclear power plant. For countries introducing nuclear power for the first time, it explains how the siting activities fit into the three phases of infrastructure development.

Section 3 provides guidance on the organization and management of siting activities.

Section 4 identifies the factors that are likely to be used to determine appropriate sites. It considers criteria in four areas:

— Health, safety, and security (covered in the IAEA Safety Series Guides);
— Engineering and cost;
— Socio-economic;
— Environmental.

It also identifies which factors and data will be used in specific parts of the site selection process.

Section 5 describes the strategy and methodology for assessing the factors described in Section 4.

Section 6 provides specific guidance on stakeholder involvement as this is a key issue for any siting project.

The Annex is comprised of a wide range of case studies.

1.4. USERS

This Nuclear Energy Series report should be used by Senior Managers, Siting Project Managers or Coordinators, and other technical specialists from:

— Governmental organizations, operating organizations, and the nuclear industry of States implementing nuclear power programmes;
— Regulatory bodies, governmental authorities and agencies;
— Organizations involved in siting and contractors providing services to the nuclear industry.

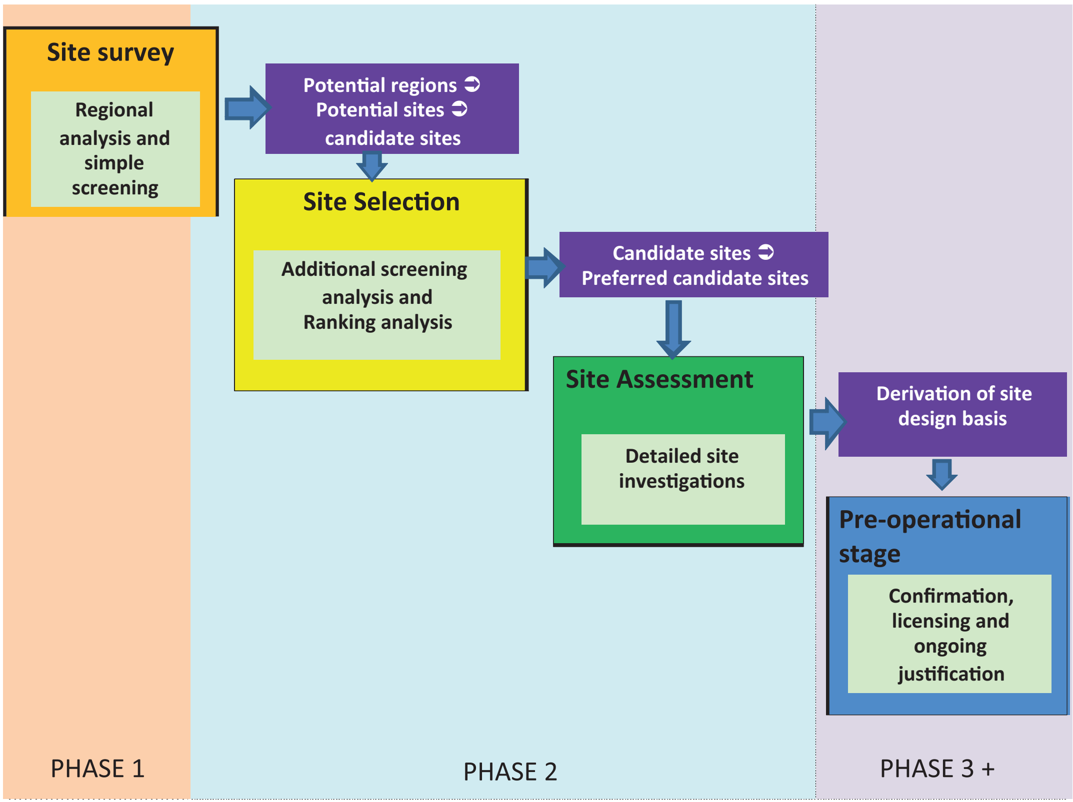

FIG. 1. Illustration of the siting process.

1.5. TERMINOLOGY

A detailed glossary of terms is provided at the end of this report. The key terminology that is fundamental in understanding the structure of this report is shown in Fig. 1.

2. SITING ACTIVITIES WITHIN THE FRAMEWORK OF THE NUCLEAR POWER PROGRAMME

This publication provides guidance to those countries that are developing a nuclear power programme for the first time but also to those countries that already have a nuclear power programme and associated infrastructure. For the latter, if there is scope to build on existing nuclear power plant sites, this may seem the obvious solution. However, most countries would still require a demonstration that such an option is 'better' than finding a new site. Thus, even in this situation, it is necessary to carry out most of the work described in this report.

It is important to recognize that the purpose of the siting activities goes beyond choosing a suitable site and acquiring a license. Issues may arise during operations that require further justification. It is essential that proper record keeping systems be established for the data collected. A large part of the project is about producing and maintaining a validated, referenced bank of data that can be used during the lifetime of the nuclear power plant.

Another important issue related to data collection is that the 'siting project' for one site may occur in several stages, with significant time lapses between them. Following an extensive review, a site might be considered suitable but not chosen for the next nuclear power plant. Subsequently, many years later it might become the selected site for a NPP. It is essential that the data collected originally are still available, both to avoid the cost of reproducing data and to provide information on how some data change with time.

The time required for justifying a site is considerable. Section 3 gives some guidance on timescales and Annex 1 contains examples of siting projects. It is important to recognize that site selection and much of the site assessment work needs to be complete before a bid invitation specification can be produced and issued.

It should be noted that a successful siting study must have stakeholder support, to the extent possible for any large industrial complex. This can be determined by assessing three influential aspects of stakeholder support:

(1) The political climate, through an assessment of the local and state positions on the potential siting of nuclear power plants. This assessment should consider historical operating organization-political relationships, the existence of current power plants, and the existence of influential 'pro- or anti' nuclear pressure groups.
(2) Public opinion related to the perceived power needs and economic value as well as environmental considerations;
(3) The legislative and regulatory climate, if known, considering the ease of obtaining permits and licenses with the current legislative regulations and the issues related to achieving environmental compliance goals. For newcomer nuclear power countries, that understanding will be developed during the development of the NPP infrastructure.

2.1. SUSTAINABLE DEVELOPMENT

In order to be acceptable to society, the selection and development of a site for a NPP should follow the guiding principles of sustainable development. The project is therefore guided by the 'precautionary principle', a concept that requires effective considerations to anticipate, prevent and correct the causes of any degradation including environmental degradation. The lack of full scientific certainty should not be used to postpone preventative measures. In this connection, applying best practice to a siting project will require that each of the four cornerstones of sustainable development is put into practice with the following as key objectives:

Governance aspects:

— Ensure transparency by providing all stakeholders with access to relevant and accurate information;
— Ensure accountability for decisions and actions;
— Encourage cooperation in order to build trust and shared goals and values;
— Ensure that decisions are made at the appropriate level as close as possible to and with the people and communities most directly affected.

Social aspects:

— Ensure a fair distribution of the costs and benefits of development;
— Respect and reinforce the fundamental rights of human beings, including civil and political liberties, cultural autonomy, social and economic freedoms, and personal security;
— Seek to sustain improvements over time by ensuring that depletion of natural resources will not deprive future generations through replacement with other forms of capital;
— Optimize utilization of human resources.

Environmental aspects:

— Promote responsible stewardship of natural resources and the environment, including remediation of any damage;
— Exercise prudence where impacts are unknown or uncertain;
— Operate within ecological limits and protect critical natural capital.

Economic aspects:

— Maximize human well-being;
— Ensure efficient use of all resources, natural and otherwise, by maximizing returns;
— Seek to identify and internalize environmental and social costs;
— Maintain and enhance the conditions for viable enterprise.

2.2. EVOLUTION OF SITING CONSIDERATIONS

Several countries implemented siting studies in the 70s and 80s but did not go on to build a nuclear power plant; they may feel that their earlier siting studies are still valid. However, site selection and licensing activities have evolved. In the past, the main criterion was to choose comparatively remote or rural areas to minimize the numbers of people at risk in the event of an escape of radioactivity.

Now, selecting sites for nuclear power installations may involve consideration of the best national option (or combination of options) for the management of high activity radioactive waste and the selection of national sites for locating nuclear power facilities. The site selection process may include a democratic mechanism that allows local communities to volunteer to host a site and could include local communities' rights to withdraw from site selection at a number of agreed stages in the process. Site selection may involve both an *open siting process* potentially available for any local community to volunteer and a *focused siting process* looking at sites where nuclear facilities already exist. Siting activities for newcomer and expanding nuclear power countries now include:

(1) Seeking consensus through a broad based participatory process;
(2) Working to develop trust;
(3) Achieving agreement that the status quo is unacceptable;
(4) Choosing the facility design that best addresses all issues;
(5) Considering a competitive siting process and working for geographic fairness;
(6) Keeping multiple options on the table at all times;
(7) Guaranteeing that stringent safety standards will be met.

2.3. THE RELATIONSHIP BETWEEN SITING ACTIVITIES AND THE DEVELOPMENT OF A NATIONAL INFRASTRUCTURE FOR A NUCLEAR POWER PLANT

This section discusses the relationship between the siting project and the wider project to develop an overall infrastructure. It is only applicable to those countries seeking to implement a nuclear power programme for the first time, or perhaps for those where the infrastructure from a previous programme has largely disappeared.

Reference 1 describes the three following distinct phases of a nuclear programme:

— Phase 1 — Considerations Before a Decision to Launch a Nuclear Programme is Taken covers the preparatory work in order to make an informed decision about a potential nuclear power programme.
— Phase 2 — Preparatory Work for the Construction of a NPP after a Policy Decision has been Taken covers the development of the infrastructure issues required to be ready to begin and supervise construction of a NPP.
— Phase 3 — Activities to Implement a first NPP covers the construction of the NPP up to the approval to commission and operate.

Associated with the completion of each phase is a milestone:

— Milestone 1 — Ready to make a knowledgeable commitment to a nuclear programme;
— Milestone 2 — Ready to invite bids for a first NPP;
— Milestone 3 — Ready to commission and operate the first NPP.

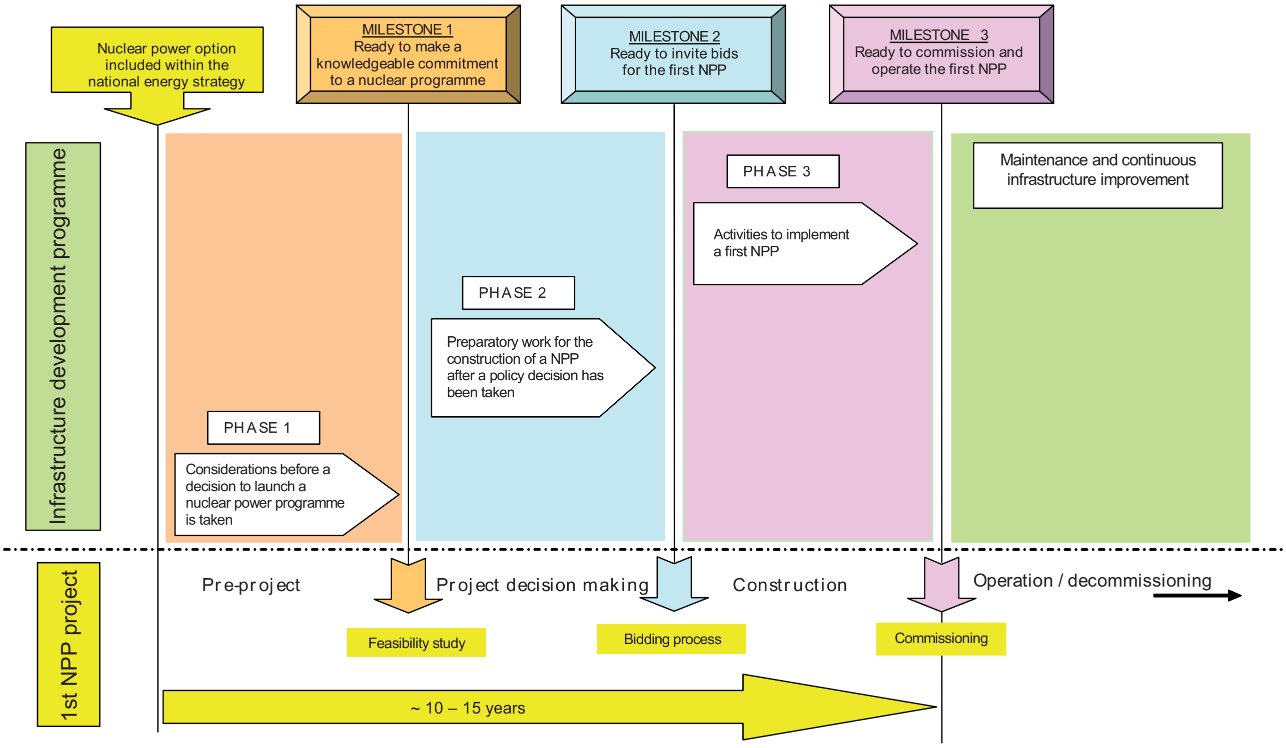

FIG. 2. Illustration of infrastructure development programme of a NPP.

The relationship between infrastructure phases, milestones and the project programme is illustrated in Fig. 2, taken from Ref. [1].

Siting activities need to begin early in Phase 1. During this phase the region of interest for a potential nuclear power plant will be established and an early review will need to be carried out to show that there are some potential sites for a NPP. Early in Phase 2, the screening and ranking analysis will need to be carried out so that a site, or sites, can be selected and the site assessment work can be planned. This will require selection of technologies that are to be considered so that any technology specific factors can be taken into account. Much of the site assessment work then needs to be carried out during Phase 2, so that the site(s) can be approved before issuing the formal bid invitation specification.

In Phase 1, the Nuclear Energy Programme Implementing Organization (NEPIO) may be the only 'nuclear power' organization in existence in the country. During this phase, it is important that the quality arrangements for managing the work are as effective as those that will be developed in the operating organization and the regulatory body during Phase 2. Thus, where initial siting related work is undertaken, before the operating organization and the regulatory body are set up, it is important to establish under the NEPIO, a management system for siting activities and an 'independent review committee' that can effectively carry out the roles of the regulatory body for these early siting activities. These are necessary in order to give the regulatory bodies, when formed, the confidence that all the work to date has been properly managed and reviewed and avoid repetition of work and potential project delays.

It is important to recognize that during Phase 2, not only is a large amount of siting work required but the organizations involved in such activities are still evolving. The Regulatory Body is likely to be established early in Phase 2, followed by the establishment of an effective operating organization. At this point, it will be clear that the operating organization is responsible for carrying out and funding the siting activities (using appropriated qualified and experienced consultants where appropriate); the regulatory body is responsible for licensing the selected sites for construction; and a government department is responsible for defining the overall nuclear policy and programme requirements. In Phase 2, it is important for the operating organization to establish a siting project team and a process for independent review of documents before submission to the regulatory authorities. The relationship between infrastructure phases, siting activities and the organizations with responsibility for siting is illustrated in Fig. 3.

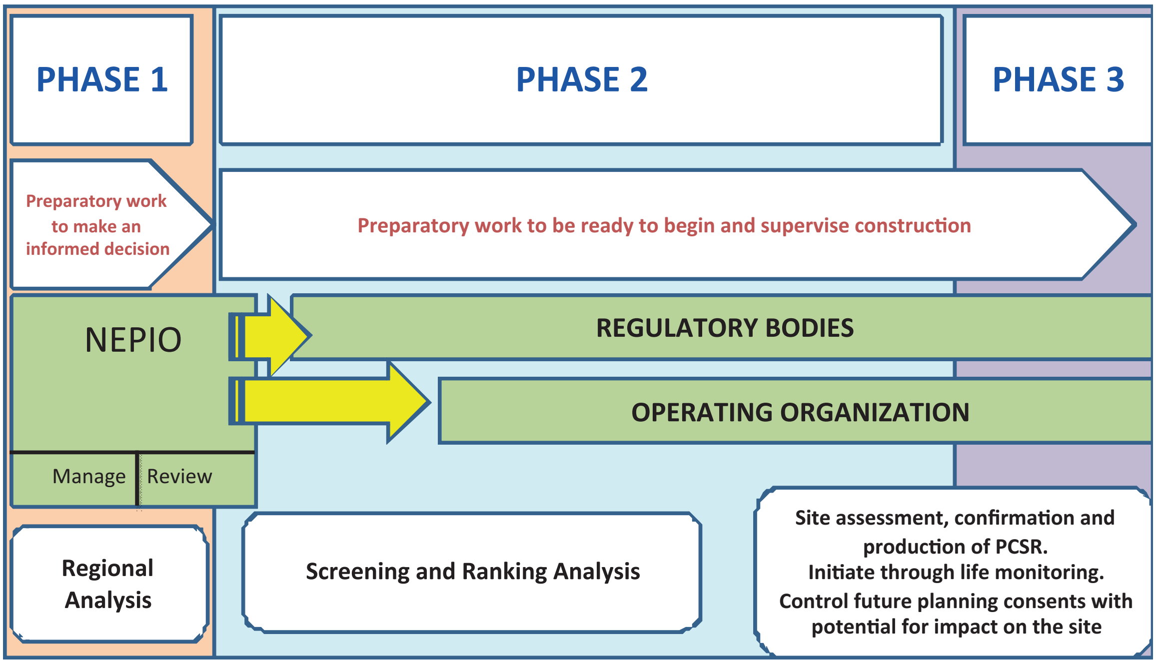

FIG. 3. Relationship between infrastructure phases, siting activities and the responsible organizations.

2.4. COUNTRIES EXPANDING THEIR NUCLEAR POWER PROGRAMME

Countries expanding their nuclear power programme face different considerations and issues to those introducing their first nuclear power plant. In these countries, regulatory bodies are already established and the operating organization looking to operate the new NPP has been identified. Some of the main issues to be considered are the following:

— Updating the regulatory framework as well as procedures and processes for site investigations;
— Evaluating the use of existing sites for additional NP units;
— Re-evaluation of sites selected several years ago with new regulations.

2.5. NATIONAL RADIOACTIVE WASTE FACILITIES CLOSE TO NUCLEAR POWER SITES

Whilst the scope of this publication is the siting of a NPP, some countries may decide to locate waste or spent fuel management facilities within the site on which the nuclear power plant is to be built. Although the criteria for siting waste processing, waste storage and spent fuel storage facilities are similar to those for a NPP, selection of a repository site will require other considerations, with special emphasis on the geological aspects of the site and long term management.

Considerations related to siting of waste facilities are not developed in this publication but are defined in the following IAEA publications:

INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Guide on Siting of Geological Disposal Facilities, IAEA Safety Series No. 111-G-4.1, IAEA, Vienna (1994).

INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Guide on Siting of Near Surface Disposal Facilities, IAEA Safety Series No. 111-G-3.1, IAEA, Vienna (1994).

INTERNATIONAL ATOMIC ENERGY AGENCY, Disposal of Radioactive Waste Specific Safety Requirements, IAEA Safety Standards Series No. SSR-5, IAEA, Vienna (2011).

INTERNATIONAL ATOMIC ENERGY AGENCY, Considerations in the Development of Near Surface Repositories for Radioactive Waste, Technical Reports Series No. 417 IAEA, Vienna (2003).

INTERNATIONAL ATOMIC ENERGY AGENCY, Hydrogeological Investigation of Sites for the Geological Disposal of Radioactive Waste, Technical Reports Series No. 391, IAEA, Vienna (1999).

Waste predisposal facilities should be considered during the siting activities for a new NPP. The processes for treatment of liquid waste as well as storage capacity for liquids are usually part of NPP design. Such facilities could therefore be co-located with a NPP. Storage facilities at NPP sites are essential, at least for interim storage. Safeguard issues related to waste storage and management have to be considered as well.

For a state embarking on nuclear power, the possibility of siting a low level waste disposal facility in the close neighbourhood of a new NPP should also be considered. It will be cost-effective if siting investigations for a NPP and for a Near Surface Repository are combined. Locating a deep repository close to a new NPP might also be worth considering during the siting project as this option help manage siting issues for the NPP and the waste facilities simultaneously.

3. MANAGEMENT OF SITING ACTIVITIES

A key requirement for managing any activity is to be clear about its purpose. Although siting activities may be grouped into 'projects' e.g. site selection or site assessment and there may be significant time intervals between different activities, there is a single overall purpose to all the siting activities. This can be defined as: "to identify and license suitable safe sites for construction of a NPP, and to assemble and maintain all site related data for the operational life of the plant and beyond." Siting is necessary to obtain permission to construct a NPP. However, it should be noted that the activities related to safety, including site licensing, will not be addressed in this publication.

The purpose of this section is to describe a management system framework for the siting activities, including organization, coordination, planning, data management, communication and stakeholder involvement.

The process of site selection and assessment is a lengthy and extensive activity requiring the engagement of a number of disciplines. The major areas considered in the selection and assessment process are:

— Health, safety and security;
— Engineering and cost;
— Socio-economic;
— Environmental.

Regulatory authorities are required to approve the site from the safety, security and environmental standpoint and have the role to review all related documentation and issue site permits/licenses to the operating organization.

The Safety Guide stipulates that "the site and the design for the nuclear installation shall be examined together to ensure that the radiological risk to the public and the environment associated with radioactive releases is acceptably low". In some States, the environmental protection authority is required to separately approve the siting project from the environmental point of view.

As noted in Section 2, for a country introducing nuclear power for the first time, the siting activities may well begin before the nuclear regulatory body has been put in place, and it is important the early work is carried out under an appropriate management system, appropriately documented and independently reviewed.

3.1. PROJECT MANAGEMENT

3.1.1. Key issues

As noted earlier, the site selection and assessment process will take place over a considerable period and involve a large number of activities and disciplines. Its management will require the expertise of an experienced project manager with a proven track record. Many of the issues will be common to other large projects and it is not the purpose of this publication to identify standard project management requirements. However, siting activities also include a number of unusual features that would not be found in many projects and the purpose of this section is to highlight these. In doing so, it will enable States to take them into account when appointing the project manager and it will provide useful guidance to the project managers themselves.

It is likely that the activities will fall into two projects with a significant time lapse between them. The first (called site selection) will be aimed at producing a list of sites that are considered suitable for a NPP and the second (called site assessment) will be aimed at detailed justification of the selected site.

3.1.1.1. Multidisciplinary project and management complexity

Siting projects are multidisciplinary and interdisciplinary projects that require a wide range of different types of interrelated competencies. Managing such projects can cause difficulties that would not be found in many projects. There is a need for siting projects to be better managed to serve the State’s requirements. Siting decisions involve complex techno-legal considerations that require constant examination and management, even apart from socio-political issues.

3.1.1.2. High level scientific content

As identified in sub-section 3.2, the level of scientific content of siting projects is very high and requires senior scientists with their own specific knowledge and experience. On the other hand there is a clear need to work very closely together. Specific experience in working with specialist consultants is also needed.

3.1.1.3. Important role of expertise and expert judgement

Siting activities require a significant amount of expert judgement, which has to be managed safely and efficiently. The safety and economic viability of the NPP are significantly influenced by these judgements; based on appropriate site studies.

3.1.1.4. Broad legal impact

The legal issues related to site selection are very broad and can include issues ranging from protection of cultural heritage to the limitations regarding slope stability.

3.1.1.5. Land purchase difficulties

Buying land for a NPP can be a difficult task as this involves different stakeholders; including environmentalists and the local population. It also requires that the site project manager understands the logistics of construction of future plant and expectations for nuclear power expansion.

3.1.1.6. Long term data management

As noted earlier, there are likely to be two projects and it is essential that data from the first project is available to feed into the second. This imposes a significant requirement on the first project. It may seem apparent, but when several sites in the country are being investigated by lots of different specialist contractors, assembling and maintaining a database of information with appropriate justifications is a difficult task.

The data management of a siting project follows a geographic information system (GIS) based hierarchical approach. A large volume of multi-source data including those describing hydro-geological, geological, and environmental characteristics are pre-processed, stored and analyzed in a geospatial database.

3.1.1.7. Team building and communication

The project team will consist of a lot of specialists in particular siting criteria and it will take special efforts from the project manager to ensure that all aspects are treated equally and that good communications are maintained. Also the organizations involved will change; the role of the NEPIO in Phase 1 will move into the operating organization, the regulatory body and the government sponsoring department.

3.1.1.8. High project cost and funding

The costs of siting activities are significant and the State needs to be clear how they are being funded. If activities start under a NEPIO, they are likely to be government funded. By the time site assessment occurs, it is likely that the operating organization is controlling the activities but it will need to be clear whether they are providing the upfront funding and how the risks of project delays or cancellation are being accounted for.

3.1.1.9. Regulatory interface

It is essential that arrangements are put in place to manage the regulatory interface and to maintain an awareness of all communications between project experts and regulatory experts. It should be recognized that as well as the nuclear regulator, there will probably be different regulatory authorities and institutions for protection of the environment, wildlife, cultural and historical heritages. More information on the regulatory aspect for siting can be found in Ref. [6].

3.1.1.10. Planning of different interrelated activities

Planning is clearly a requirement of any project but where there are lots of sites to be evaluated, lots of data to be obtained or collected (some of which will require a considerable elapsed time), lots of specialists to be engaged and legal and ownership issues to be addressed, the plan needs to recognize the timescales for these types of activities. They will probably dominate the programme, rather than issues associated with work load and resources. Planning also needs to include quality plans.

3.1.1.11. Legislative aspects

Siting activities should be addressed by the national nuclear legislation in particular within the provisions on the authorization process for nuclear power plants. In any case, the law should clearly define the regulatory responsibilities with regard to siting activities and the main requirements.

3.1.1.12. Stakeholder involvement

In general the issues here are similar to any major industrial project. There will be those keen to share in the economic benefit, those supportive of the project so long as it is 'somewhere else', and various anti-groups. What is clear is that stakeholder involvement is especially important in a siting project.

In fact stakeholder involvement is a necessary and desirable part of the siting process, in order to consult with and include interested and affected individuals in the selection and decision process. It is now impossible to implement nuclear projects without a considerable amount of active consent from stakeholders. Authorities and operating organizations also face extremely high scrutiny from stakeholders.

The critical element is that all stakeholders should be involved early, substantively, and frequently in the site selection process. Engagement of all stakeholders requires:

- A clarity of purpose;
- A commitment to use the process to inform project actions;
- Adequate funding and staff;
- Appropriate timing in relation to decisions;
- Full government support (providing legitimacy to the process).

Further guidance on stakeholder involvement is given in Section 6.

3.1.1.13. Education and training

The siting project may well bring requirements for skills not previously developed in the country. The project may therefore provide an opportunity to develop a range of technical disciplines in universities or industry. The project manager may also need to include staff to shadow experts and learn new skills.

3.1.2. Project risk management

Nuclear power plant projects usually hold a high degree of risk. Several of those risks are connected with the site itself, but an integrated approach to risk management is necessary. The overall approach needs to take into consideration the following issues:

— High capital cost and loan interest rates;
— Higher risks of non-completion compared to other power plants;
— Market demand;
— Unplanned shutdowns;
— Liabilities for decommissioning and site-restoration;
— Regulatory risks, retrospective safety regulations, mandated shutdowns;
— Early shutdowns for political reasons;
— Level of public support for the project;
— Unknown risks.

These risks are the direct result of the:

— Chosen site;
— Chosen technology;
— Fuel supplier;
— Chosen, design and vendor;
— Government policies (national and/or regional);
— Commercial and financing arrangements.

The site will influence the plant technology and design and will affect the influence of stakeholders on local and national government, while the governmental jurisdiction over the site will reflect in not just the regulatory issues, but also licensing, subsidies policy and market pricing. A great deal of predictability in governmental reaction will be needed in these issues if the investors are to minimize the associated risk for their investment. Project risk management aimed at reducing the risks with deployment of new NPPs entails:

— Financial criteria (notably profitability and usually assessed with the Net Present Value method);
— Clear shares of profit return;
— Proper allocation of risks and rewards for the parties assuming the risk (requiring proper contracting and well planned siting and construction processes, without delays);
— Liability for policy changes;
— Legal recourse for arbitration;
— Exit strategies;
— Responsibilities for plant retirement, long term waste management and site restoration.

More details on project risk management can be found in Refs [7, 8].

Key areas of risk management for the siting activities relate to quality and availability of data, appropriate decision making with all factors identified and appropriately weighted, and stakeholder management. These are all addressed in the appropriate sections of this publication.

3.1.3. Integrated quality management

Siting activities should be integrated within the overall project quality arrangements, recognizing that they may be initiated long before the NPP is established.

The application of best practice principles for a project begins at the conceptual phase and continues throughout all of the stages of the project. In effect, best practice principles are continually developed and improved upon for any project as it moves through the stages of the cycle and as more information is collected and a better understanding gained. Generally, this commences with baseline data collection.

An Integrated Quality Management approach is applied to provide a single framework for all the requirements in the siting process, and should provide confidence that those requirements are, or will be, satisfied. It ensures that health, environmental, security, quality and economic requirements are not considered separately from safety requirements, to avoid the possibility of their potential negative impact on safety.

Some of the activities that are entailed in Integrated Quality Management will be training of personnel, self-assessment, validation and verification procedures, standards for collection, processing and analysis of data, etc. A complete programme would additionally include the following:

- Statement of policies and objectives;
- Clear definition of the items and services covered by the programme;
- Outline of the organization structure in which quality management activities are to be planned and carried out;
- Defining roles and responsibilities of organizations and personnel involved in the programme;
- Describing procedures that will be applied to ensure the effectiveness of assessments and engineering activities performed in each stage of the siting project;
- Describing methods used to plan and carry out activities;
- Maintaining records on personnel training and qualifications;
- Specifying the documentation used for communicating instructions, information and results within, from and to the organization;
- Maintaining records of all work carried out;
- Referencing the appropriate sources that were used to obtain information;
- Documenting the results of studies (including models and simulations) and investigations in sufficient detail to permit independent review;
- Summarizing the results of all investigations and analyses.

These expectations apply to all activities that may contribute to the derivation of parameters that will ultimately contribute to the selection, assessment and confirmation of the site. The process of site selection and assessment involves technical and engineering analyses, along with judgments that require extensive experience and knowledge. In many cases, the parameters and analyses may not lend themselves to direct verification by inspections, tests, or other techniques that can be precisely defined and controlled. In these cases, assessments are reviewed and verified by individuals or groups that are independent of those who did the work.

Experienced engineering judgment and expertise in geotechnical engineering is an important aspect of assuring the quality of the site selection and assessment process. For example, in the assessment of matters such as liquefaction potential and slope stability, the accuracy of the results depends heavily on insights into failures that have occurred in comparable situations. The information gathered from these assessments is documented and analyzed to provide evidence that similar failures will not occur.

It is a good idea to carry out a peer review during the implementation of a siting project, allowing evaluators to resolve comments as the technical issues arise (quality verifications). This will decrease the likelihood of the study being rejected at a late stage. Usually, it is performed by a team or organization, appointed by the site owner. A final peer review is carried out toward the end of the study together with a follow up review that all actions have been implemented.

3.1.4. Data management

Managing the siting project documents is an important part of quality management so that all data, judgments and conclusions are traceable. This means that each document should be identified by time, place and by whom it was created, modified and published, and the document system should identify and control where it is stored. It should be noted that the data quality depends upon the methodology for collection as well as the instrumentation used, both of which fall under quality management.

A particularly crucial activity is document control and data management. There will be various supporting documents created to support the siting process (e.g. calculations, reports, drawings, specifications) and the siting process will involve the collection of vast amounts of data for further analysis. As well as ensuring that these data are properly referenced and maintained for a long period, consideration should be given as to the best method of data organization to facilitate its use and to highlight areas where data have not yet been obtained. Key data management activities include:

— Collecting, protecting and maintaining traceability of data;
— Identification of the source of data and reliability;
— Establishment of the format of data;
— Analysis of data and documenting conclusions;
— Identification of the qualifications of data analysts and evaluators;
— Tracking changes in data and conclusions.

3.1.4.1. Data management tools

The data management of a siting project should consider using a GIS based hierarchical approach for managing the large volume of multi-source data (GIS based tools are the most common tools for sophisticated data analysis).

Three categories of tools can be applied for data management including data collection, processing, analysis and maintenance:

(1) Tools recommended or required by Regulatory Bodies (whether nuclear safety or environmental protection), such as the ones provided in Refs [9–11];
(2) Commercially developed tools by specialized (consulting) enterprises. Examples can be found as in Refs [11–13]. The public domain also holds GIS tools that can be used in the siting process for data analysis, though specialized GIS tools are typically commercially available;
(3) Internally developed tools, especially for the siting purposes. This can be done by specialists inside the siting team, or in cooperation with academic and/or other research institutions. Examples of such tools can be seen in the case studies of Morocco and Brazil.

Selecting one of these tools for utilization will depend on the objectives of the siting team. The first category is obligatory if the Regulators require it. However, experience shows that tools from the second category can be just as, if not more, powerful in data processing and analysis, justifying their relatively high price. The third category of tools is one of the means for capacity building, building human resources, and national involvement in the nuclear programme.

3.1.4.2. Data availability

It is essential to have data which is sufficient and precise enough to provide a valid conclusion for the site under consideration. It also eliminates the possibility of a ‘fatal flaw’ that can result in discarding the site after a lot of resources were invested in it. Data can be acquired from various sources:

— Specific databases or archives of specialized institutions (Ministries, Institutes, Scientific Centres, Universities, etc.), the gathered data may have some gaps or insufficient scope, and it is also important to consider the data reliability;
— Local groups or organizations, engaged through the public participation process, can provide additional information or point to an aspect which might not be considered in the above records;
— Data can also be derived from previous siting studies done for either a nuclear or any other industrial facility. In this case though, re-evaluation and/or validation of data may be required, since in many cases the methodology might not be available, or simply outdated;

— Data can be collected through field surveys, sampling, measurements and observations at the potential sites. The scope of such a programme for data gathering will depend on how much information is needed for a reasonably precise impact prediction or for validation of older data. The credibility and usefulness of the newly collected data may depend on the period of time which was covered with the measurements or observations (meteorology, oceanographic, biodiversity, etc.) It is, therefore, also important that the measurements reflect the temporal variations of the measured value.

3.2. ROLES AND ORGANIZATION

3.2.1. Siting team

3.2.1.1. Terms of reference

The Siting Team has the overall responsibility for implementing siting activities for the period and purpose defined in its project terms of reference. This could be limited to the site selection activities or it could also include site assessment and acquiring a site permit.

The siting team will include experts familiar with each principle discipline involved (see Sub-section 3.3) together with those able to collect and process local information. It will also include those with expertise in decision making through ranking and other similar techniques. Some experts will have knowledge in more than one discipline and may undertake the ‘intelligent customer’ role (see next section) when purchasing specialist services from consultants. For disciplines related to more important site characteristics, a full time team member may be selected.

It is important that all the required expertise is included from the beginning as a complete understanding of the commitments and requirements can only be achieved by establishing a fully competent siting team.

This team may evolve and belong to different organizations during the implementation of the siting activities.

3.2.1.2. The intelligent customer role

The siting team will need to procure expert services across a range of subject areas. Some of these will be specialist contractors, for example in rock and soil structure characterization. It is important that the siting team have enough expertise to know what is required and who is carrying the risks associated with unknown or developing information.

3.2.1.3. Organization

The siting team should report to a senior director of the nuclear power programme and should be given appropriate time and resources (financial, human and logistic) to carry out the necessary investigations.

A siting team composed of 10 to 15 professionals is usually considered adequate, but additional consulting services are likely to be required from time to time. The number of professionals also depends on the safety specialists to be involved and this part is further developed in the IAEA Safety Guides [2–6].

An example of a possible structure is shown in Fig. 4.

The exact organizational chart will depend on how the siting project fits in with the overall project, particularly whether the project is to implement a new nuclear programme or to add a NPP on an existing site. In some cases, the group is a virtual team under matrix management.

The key requirement is to ensure that all the required disciplines will be covered by the project team internally or through use of external expertise. A general list of disciplines and activities for each stage is given in Table 1, Sub-section 3.3.3. It offers guidance for the siting team management in organizing the human resources as the process advances through the various stages. In general, more disciplines and activities are brought into each stage, and every one of them has to be addressed in greater detail as the project progresses through the stages. It is important that the roles and responsibilities of each team member are clearly defined and approved by the project manager. It is also important that evidence is provided to show that each team member is suitably qualified and experienced for the assigned role.

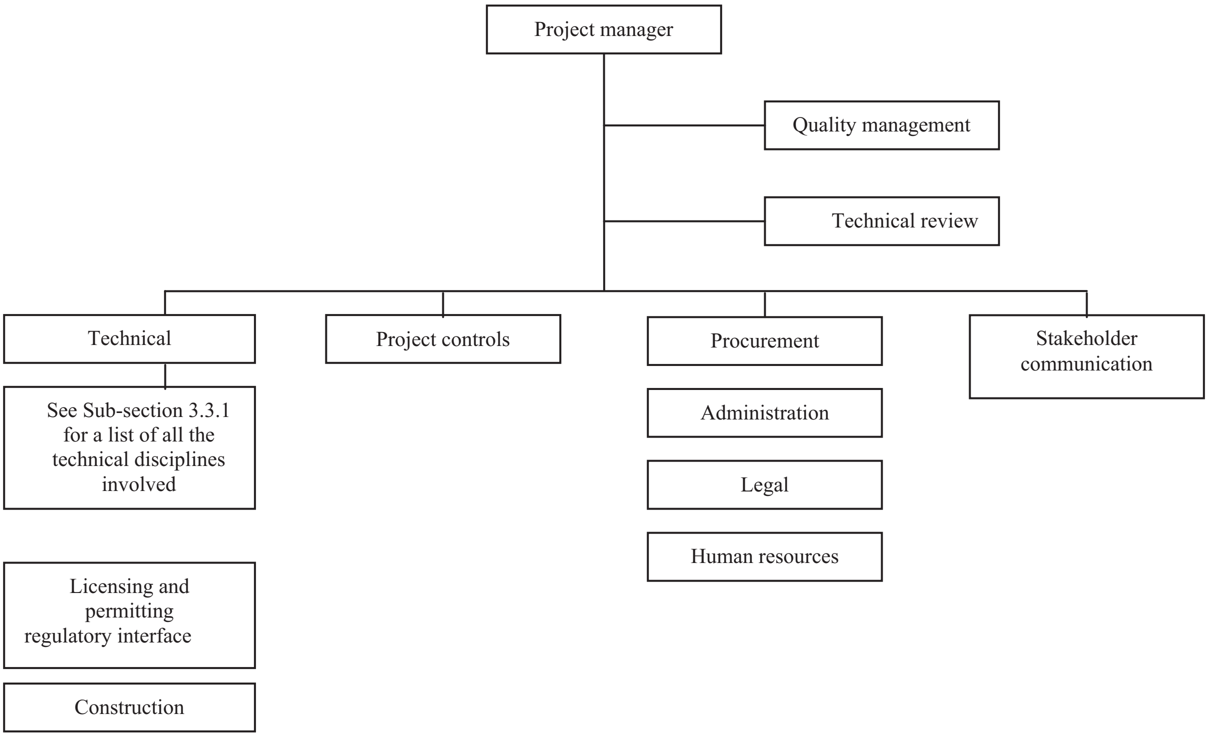

FIG. 4. Example of siting team/group organization.

3.2.1.4. Technical Review Group

The Technical Review Group is an important and essential element of ensuring the quality of siting assessments and decisions. As noted earlier, siting decisions require inputs from many specialized areas and it is important that the project manager has sound advice from those able to provide independent review of key documents and conclusions. They help ensure sound judgements and consistent interpretations of key technical and specialized issues. The members should be independent of those carrying out the work and should report directly to the project manager.

3.2.2. Regulatory framework

As the siting process involves a significant number of safety related issues, this work is performed within the nuclear regulatory framework. This should be consistent with the IAEA Safety Guides on siting [2–6].

Depending of the country's legal system, there may also be several other approvals needed from government organizations/regulators such as those responsible for the protection of the environment, wildlife, cultural and historical heritages. It will be necessary to coordinate between the nuclear regulatory body and other local and regional organizations and governmental agencies that have related roles. It is suggested that arrangements for communication between organizations and with other stakeholders are clearly set down and agreed.

As noted in Sub-section 2.3, the siting activities may have started before the regulatory body has been formed and during this time the independent review committee, part of the NEPIO, should fulfil the regulatory role.

3.3. DISCIPLINES AND ACTIVITIES

3.3.1. Technical disciplines

- Demography, population distribution;
- Meteorology;
- Hydrology and hydrogeology;

TABLE 1. RELATIONSHIP BETWEEN THE MAIN ACTIVITIES AND THE TECHNICAL DISCIPLINES

TYPE OF ACTIVITY / TECHNICAL DISCIPLINE AND SITING ASPECTS	COMPILATION STUDIES & EXISTING DATA			FIELD OBSERVATION AND EXPLORATION			FIELD TESTING, MEASUREMENT AND MONITORING			LABORATORY TESTING			ANALYSE & CALCULATIONS		
	STAGES			STAGES			STAGES			STAGES			STAGES		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
GRID INFRASTRUCTURE	X	X			X			X	X		X	X		X	X
LAND USE	X				X			X						X	
DEMOGRAPHY, POPULATION DISTRIBUTION	X	X			X									X	
FEASIBILITY OF EMERGENCY PLANNING	X	X			X			X							
ENVIRONMENTAL IMPACT ASSESSMENT	X	X			X	X		X	X		X	X		X	X
ENVIRONMENTAL MONITORING		X			X	X		X	X		X	X		X	X
VOLCANIC HAZARD	X	X			X			X	X		X	X		X	X
SECURITY		X			X									X	X
SEISMOLOGY	X	X			X			X	X		X	X		X	X
GEOLOGY	X	X			X			X			X			X	
HYDROLOGY & HYDROGEOLOGY	X	X			X			X	X		X			X	
METEOROLOGY	X	X			X			X	X		X			X	
OCEANOGRAPHY	X	X			X			X			X			X	
HUMAN INDUCED EVENTS ASSESSMENT	X	X	X		X			X			X			X	X
EXTERNAL NATURAL HAZARDS OTHER THAN EARTHQUAKES	X	X	X		X			X			X			X	X
GEOTECHNICAL, EARTHWORK & FOUNDATION	X	X			X	X		X	X		X	X		X	X

— Environmental monitoring and environmental impact assessment;
— Geology;
— Seismology;
— Volcanology;
— Geotechnics, earthwork and foundation engineering;
— External human induced event assessment;
— Security;
— Analysis of feasibility of emergency planning;
— Land use;
— Archeology;
— Grid infrastructure ;
— Oceanography.

3.3.2. Other supporting disciplines

— Human resource and training;
— Stakeholder involvement;
— Procurement;
— Legal;
— Project management;
— Quality management;
— Permitting and licensing;
— Environmental justice.

3.3.3. Technical activities

3.3.3.1. Compilation of studies and existing data

The data compilation studies include:

— Compilation of literature;
— Compilation of instrumental data;
— Compilation of historical data.

3.3.3.2. Field observation and exploration

The field observation and exploration activities include:

— General observation for a better appreciation of site characteristics;
— Confirmation of site characteristics obtained from literature, maps, photographs;
— Decision making for particular aspect of sites.

3.3.3.3. Field testing, measurement and monitoring

The field testing, measurement and monitoring include:

— Sampling for direct observation;
— Sampling for in situ testing;
— Sampling for laboratory testing;
— Logging, shipping and storing of samples;
— Measurement and testing of samples;
— Direct measurement by field instruments or testing;
— Field monitoring programme.

3.3.3.4. Laboratory testing

The laboratory testing includes:

— Sample testing and measurement;
— Model studies.

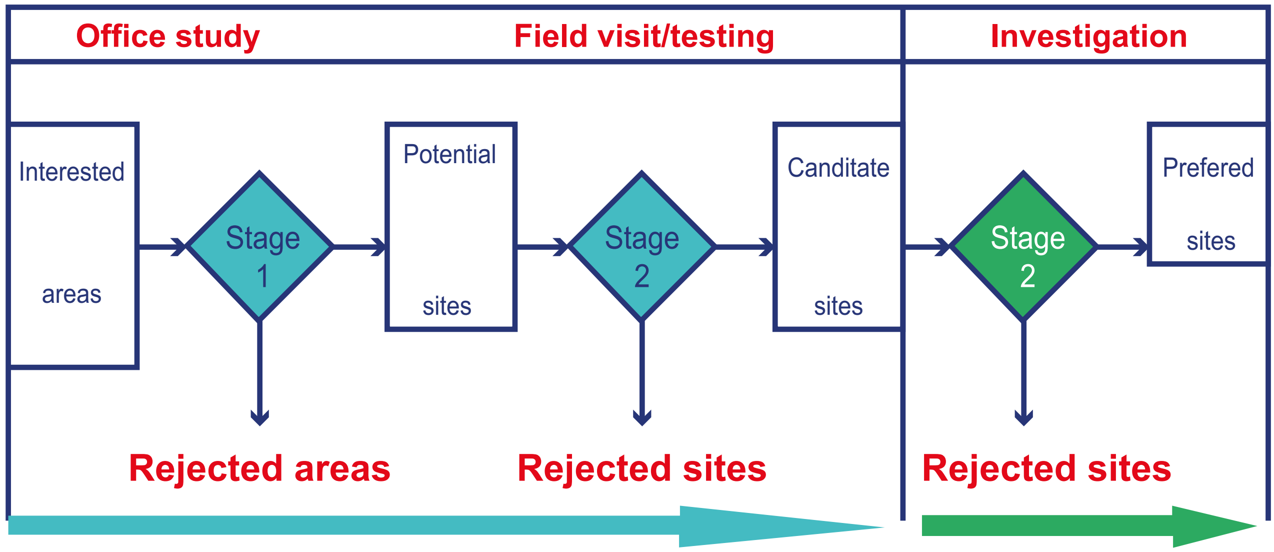

FIG. 5. Types of activities required.

3.3.3.5. Analysis

The analysis includes:

— Data processing, reduction of test data;
— Expert evaluation and judgement to assess relevant data;
— Calculation for derivation of preliminary design parameters;
— Calculation for derivation of final design parameters;
— Calculation to assess sensitivity of results to input parameters.

3.3.3.6. Process

The first three stages of the process are illustrated in Fig. 5.

3.3.4. Other activities

3.3.4.1. Stakeholder involvement

As previously explained, stakeholder involvement is a critical part of the siting process. Stakeholder involvement activities could include informal networking (small meetings and briefings); building communication channels with local and regional government officials; forming a review or advisory group that includes stakeholders; contacting local organizations, universities, government technical institutes, etc. to obtain information, data, expertise; establishing an information centre or website for public access; issuing periodic reports and/or newsletters; conducting workshops and open house. See Section 6 for more details.

3.3.4.2. Cost estimating

The siting team will need to evaluate the costs of different approaches, methods, and options.

3.3.4.3. Report preparation

A siting report, or set of reports, will need to be prepared to document the process and results of the siting work. The report will need to address the requirements of the regulatory bodies.

3.3.4.4. Responding to requests for additional information

Regulatory bodies, government bodies and stakeholders will request additional information and it is important that all such communications are logged and that information provided is consistent.

3.3.4.5. Quality management

As stated in Sub-section 3.1.3, the whole project requires quality management procedures to be put in place, at all stages of the siting project. Quality management activities of particular relevance to a siting project, include:

- Control of software;
- Development and adaptation of software;
- Applying industry standards for computer programmes;
- Verification and validation of computer programmes and data;
- Management of maps, drawing, photographs;
- Implementing the quality plans (data, traceability, manpower etc.);
- Siting project self-assessment;
- Siting project Peer Review.

3.4. TYPICAL SITE RELATED CONTENTS IN NPP CONTRACTS

In nuclear power plant contracts, there will be site related content that has a high impact on the engineering and cost of the nuclear power plant. This is likely to include the following issues:

- Location: required for logistics for transporting materials, equipment, etc.;
- Elevation: required for many reasons but the most critical are site security from flooding, tidal waves, tsunamis etc.;
- Water temperature data: a design requirement for sizing pumps, heat exchangers, etc. and is required for every month of the year;
- Silt conditions: a site specific condition which can be present in rivers or estuary conditions;
- Tide or high and low water levels: critical for some sites but also needed for depth layout of main and turbine building;
- Bathymetry: dealing with silt conditions and could become critical for design of intakes and discharge;
- Chlorination requirements: depending on environmental rules in place at the site;
- Meteorological conditions: includes wind data, temperature, humidity, precipitation (snow, rain);
- Seismic: the standard design ground response spectra for the horizontal and vertical directions along with the corresponding damping, acceleration and velocity values;
- Geotechnical design parameters: includes foundation material dry, saturated and natural densities, static modulus of elasticity, static poison’s ratio, seismic wave velocity, dynamic modulus velocity, dynamic poison’s ratio, dynamic shear modulus, foundation bearing capacity;
- Raw fresh water quality: required for design of water treatment plant and production of concrete, washdowns, etc.;
- Electrical grid conditions and electrical distribution voltages.

3.5. DURATION OF ACTIVITIES

It is not possible to give precise guidance on the time or resources required for a siting project. It depends on the siting criteria, the availability of data, the nature of stakeholder interaction required, the regulatory process and many more factors. The following can only be considered as an approximate indication. Some real examples are given in Annex I (see Sub-section 3.6).

3.5.1. Site survey stage

The stage where surveys are conducted for identifying several potential sites or appropriate areas and simple screening of potential sites is carried out resulting in finding appropriate candidate sites. Typically, this involves a duration of about 9–12 months after establishing the siting core team.

3.5.2. Site selection and assessment stages

The stages where preferred candidate sites are identified through ranking analysis and particular sites are selected for detailed study by the siting team. This involves a duration of about 12–36 months during which the site is selected, assessed and completely characterized. This period is obviously dependent on the available resources, including human and financial, but is mainly based on the fact that 12 months are required to measure relevant data.

3.5.3. Pre-operational stage

This stage involves the confirmation of the site suitability by the operating organization and the receipt of the required permit/confirmation from the relevant regulatory authorities, indicating that a nuclear power plant can be built at the selected site. It also includes the entire period under which the nuclear power plant will be built and the site prepared for the safe and secure operation of the nuclear power plant. This involves a duration of about 5–7 years, equivalent to the nuclear power plant construction duration and includes site preparation, monitoring and licensing by the relevant regulatory authorities.

3.6. EXAMPLES OF SITING PROJECTS

Annex I contains several case studies of siting investigations. These include examples of countries carrying out studies for the first time, countries with a nuclear power programme looking for new sites and countries looking to use an existing site.

It will be clear from these case studies that the periods suggested in Sub-section 3.5 are only a guide and will vary considerably from case to case.

4. CRITERIA FOR SELECTION AND ASSESSMENT OF NPP SITES

Section 5 will detail the multi-stage process used to select sites; with each stage considering additional factors and requiring more detailed information. As an introduction to the factors themselves, which are the subject of this section, Sub-section 4.1 gives an overview of the methodology. Sub-section 4.2 describes the various types of siting criteria, and Sub-section 4.3 introduces the concept of the plant parameter envelope which will provide the NPP related data for assessing the criteria. Sub-sections 4.4–4.7 explain the factors that need to be considered in defining the site selection and assessment criteria and these form the majority of this section. These sections also identify the stages in which these factors are likely to be used and the types of data that are required.

4.1. OVERVIEW OF METHODOLOGY

The starting point for a siting investigation is the desire to place a nuclear installation in a particular region. This region will be fairly large; it could be a whole country or an area of a country.

Clearly the problem of finding the most suitable sites involves evaluating a large area against a large number of criteria. As explained in the following sections, these criteria cover:

- Health, safety, and security (covered in the IAEA Safety Series Guides);
- Engineering and cost;
- Socio-economic;
- Environmental.

The amount of information required could be prohibitively expensive and so large as to make it impossible to handle. For this reason a multi-stage process is proposed. Figure 1 illustrated this process and it is discussed in more detail in Section 5.

Stage 1, called the Site Survey Stage, involves the investigation of potential regions and potential sites, and the rejection of unsuitable sites through some screening analysis. It results in a list of candidate sites.

Stage 2, called the Site Selection Stage, involves the review of candidate sites by further screening and ranking, leading to preferred candidate sites and the final site selection by the operating organization. Ranking is based on a wide range of criteria covering safety, environmental, socio-economic, engineering and cost issues.

Stage 3, called the Site Assessment Stage, involves justification of the acceptability of the site based on detailed investigations and characterization of the site. It results in the derivation of the site related design basis.

Stage 4, called the Pre-operational Stage, involves the formal confirmation of the suitability of the site and the preparation and submission of a licence application to the regulatory body. It also involves the ongoing monitoring of the site before operation to confirm acceptability of the site.

Siting activities continue beyond stage 4 as there is a need for continuing monitoring of the site to confirm it meets the design intent and for potential re-evaluation of some aspects required as part of Periodic Safety Reviews. However, this aspect is not discussed in any detail in this report.

The previous process description starts from the assumption that a whole region is being reviewed for potential sites. In practice, a country may have done this some time ago in order to select earlier sites for nuclear installations. If these sites have space for additional units, it may be clear to those responsible, that building on these existing sites is the best approach and that the site survey and selection stages described above are not necessary. Nevertheless, some consideration needs to be given to this part of the process in order to justify the decision and to demonstrate that there is not now a better site.

4.2. TYPES OF SITING CRITERIA

Sub-sections 4.4–4.7 list a wide range of possible factors that may be relevant to a country’s siting decision. The list is based on the experience of those countries that have already carried out siting studies. However, each country needs to develop its own national list of criteria. Some of the factors listed here may not be relevant and it is possible that the country has some specific national criteria that are not included here.

If the criteria developed are too general, they will not narrow down the areas of interest sufficiently. Equally, if the criteria are too limiting, the process may eliminate all sites. For example, a review may be based on a certain technology with a defined seismic capability and using sea water cooling. It may then find that there are no suitable sites in which case it will be necessary to repeat the exercise allowing cooling towers and/or greater seismic capability (recognizing the additional costs) to select sites.

Three criteria types: exclusion, avoidance and suitability are usually defined.

4.2.1. Exclusion criteria

These represent requirements that, if not satisfied by site conditions, would preclude the construction of the NPP at that location. Exclusion criteria are used early in the siting process to eliminate areas based on consideration of go/no-go situations and are generally based on regulatory and/or plant design requirements.

4.2.2. Avoidance criteria

These are not strictly go/no go criteria but are utilized to identify broad areas with more favourable than unfavourable conditions. For example, a higher water table increases construction costs and flooding risks, while ease of access to cooling water reduces operating costs. Application of avoidance criteria helps ensure that the siting approach is manageable but still effective in identifying the most suitable sites.

4.2.3. Suitability criteria

These are the factors that affect the relative suitability of developing the site, but do not have ‘unacceptable’ levels. Examples would include ease of site access and transport costs, closeness to load centres, cost of cooling water systems. Evaluation of sites with respect to suitability criteria requires assessing trade-offs among the various criteria selected by the country. These factors are used in the latter stages of the siting process, once the exclusion and avoidance criteria have been used to reduce the number of sites being considered.

For suitability criteria, it is necessary to construct the list of criteria in such a way that they can be scored, weighted and ranked appropriately. For example, if one issue is expressed in 5 different sub-criteria, it is likely that it will contribute too much in the overall decision making unless it is clearly recognized that the sub-criteria are one single issue and therefore should not be given more weight than another single issue. An example of actual criteria used in one country is provided in the USA case study.

4.3. NUCLEAR POWER PLANT PARAMETER ENVELOPE (PPE)

At the beginning of the siting project, the type of NPP that will be deployed is not usually determined. In order to select an appropriate site without knowing the actual NPP parameters, it is necessary to establish a Plant Parameter Envelope (PPE) for the nuclear power plant. This gives the potential range of values for the basic NPP parameters that impact the proposed site. The NPP information included in a PPE (composite or otherwise), should provide answers to the following major issues:

- The region or regions requiring a NPP;
- An estimate of the amount of electricity required for each region;
- A shortlist of the potential technologies that might be used;
- Site characteristics that are required to support the safe and secure operation of a nuclear plant (e.g. availability of cooling water, ambient air temperature, etc.) and meet national obligations and commitment with regard to non-proliferation and safeguard;
- The capability of the nuclear plant to withstand the natural and human-made environmental hazards associated with the site (e.g. earthquake, tornado, potential floods from nearby dams, snow load, rainfall, etc.) with indications of how costs vary with increasing hazard size;
- An understanding of whether more than one unit might be possible on one site and how this affects the site requirements;
- Land requirements (building height, deepest foundations, area);
- The impact of the nuclear plant on the site’s natural and environmental resources (e.g. potential increases in water and air temperatures, water use, gaseous and liquid releases of radioactive material).

Some documents such as the Utility Requirements Document (URD) or the European Utility Requirements (EUR) that present a clear, complete statement of utility requirements for the next generation of nuclear plants, could be used as generic design basis considerations for NPP siting.

4.4. HEALTH, SAFETY AND SECURITY FACTORS

The relevant factors are listed below and are covered in a separate publication which is part of the IAEA Safety Standards Series [2]. To provide a complete and balanced view of all the factors that need to be considered, this report provides a list of the health, safety and security factors but does not develop them in any detail.

4.4.1. Magnitude and frequency of natural external events

These include (though there may be others):

— Seismic hazard — active faults, design basis earthquake;
— Geological hazards — volcanoes, liquefaction, collapse, subsidence, landslides;
— Flooding;
— Coastal — wave action, storm surges, seiches, tsunamis;
— River flooding — including those due to dam breaks;
— Extreme meteorological events — hurricanes, tornadoes, tropical storms, straight winds; icing, snow, hail, lightning, draught, extreme precipitation, sandstorms, etc.;
— Biological events (biofouling of cooling water intake).

4.4.2. Human induced external events

These include (though there may be others):

— Airplane crashes — including impact, fire and vibration type loads;
— Explosions from transport accidents (including drifting clouds) — trucks, railway, tankers, gas carriers;
— Explosions from fixed installations — arsenals, gas storage facilities, gas pipelines etc.;
— External fires — brush fires, forest fires;
— Ship collisions or shipwreck;
— Toxic liquid/gaseous releases, radiological releases.

4.4.3. Characteristics related to radiological impact

These include:

— Transport and dispersion in air;
— Transport and dispersion in ground water;
— Transport and dispersion in surface water;
— Population and emergency preparedness aspects;
— Distance from population centres;
— Population density;
— Special population groups (hospitals, prisons etc), transient population;
— Requirements for exclusion area and low population area;
— Natural conditions for emergency preparedness;
— Infrastructure availability for evacuation.

4.4.4. Security and safeguard

These include:

— Electro magnetic interference;
— Security threats;
— Site organization with regard to safeguard implementation.

4.4.5. Essential supplies

These include:

— Ultimate heat sink;
— Electrical supplies.

4.5. ENGINEERING AND COST FACTORS

The engineering and cost factors are mostly used for site survey and selection. They could be very important for the site owner in ranking areas and sites.

4.5.1. Suitability of water for cooling

4.5.1.1. The issues

NPPs are cooled by water and the cost and availability of an adequate supply of cooling water are very important considerations. Evaluation of water supply capability should also include the effects on water quantity left in the source water body and the effects on water quality as a result of reduced waste assimilation capacity. The quantity of water depends on the adopted system, the power of the plant, the condenser design and the temperature of the cooling water. The following cooling systems are used for a NPP:

— Once-through cooling system. These are cheaper to construct than evaporative cooling systems. However, they can increase the temperature of the source water by several degrees and the impact of this has to be assessed. They require large volumes of water (at least 50 m^3/s for a 1000 MW NPP). Sea water cooling is preferable if available, due to the greater effect of dilution on water temperature.
— Recirculating wet cooling system (closed loop system). These use cooling towers but still require significant quantities of water (between 2–4 m^3/s for a 1000 MW NPP). If fresh water is being used, this is the preferred option. These systems consume more electricity than once-through systems.
— Dry-cooling system. These rely on air flow to cool water flowing inside tubes or pipes and require significantly less water than a wet cooling system. However, they are a lot more expensive to construct and impose an additional capital cost of about 3–5%, as well as using approximately 1.5% of the average annual electricity production.
— Hybrid cooling system. These are a combination of wet cooling and dry cooling systems through use of a wet cooling tower and an air cooled condenser.

For plants on a river site, minimum/maximum flows, selection of intake location/invert level with respect to sedimentation/erosion and stability of banks are important considerations. For plants on coasts, flood levels/recedes, pumping head, bathymetry, water chemistry and stability of shore are important considerations.

Constructing pumping stations and developing infrastructure, to transport water from the source to the site, results in an increased construction cost of the nuclear power plant. In addition, any right of way or land lease costs associated with water transport as well as the operational costs (e.g. pumping power) need to be taken into account as factors for site selection. An avoidance distance could therefore be set, based on professional judgment as to the range of distances likely to be available and the likely costs.

Other important considerations include the water licences and authorizations needed.

4.5.1.2. Use

These factors can be used in stage 1 as exclusion or avoidance criteria to eliminate areas and sites where the costs of providing adequate cooling water would be prohibitively expensive. They will also be used in selecting and ranking sites based on detailed assessments of water requirements, availability, authorization, costs of providing the water, impact on local water temperatures. This will require information on the water source flow rates and any ‘tidal issues’.

4.5.2. Suitability of existing electricity infrastructure

4.5.2.1. The issues

A major practical consideration in the location of new NPP is that potential sites should be strategically placed, both for connection to the transmission grid and to supply electricity to large areas of demand. An important factor is the ability of the grid system to accept power in-feed at a particular site location without requiring costly and time consuming reinforcement. Moreover, due to their high capital cost and low running costs, a NPP should be sited so as to operate as a base load plant and the grid infrastructure should enable its continuous operation at full power. The objective of the siting studies is to evaluate the connection of new NPPs to the transmission system grid, to determine if the capacities of the existing transmission lines and switchyards are adequate to handle the additional power, and if not to evaluate the costs of doing so. It should be noted that the approval of any new grid lines can sometimes be harder to achieve than authorization of the site itself.

The stability of the grid system in the event of the sudden shutdown of a NPP and the effect of a large loss of grid load on the plant have to be evaluated as part of the review of site suitability. A nuclear power plant requires adequate and reliable startup power and therefore reliable offsite power has to be assured. (There may also be safety requirements related to reliability of off-site power). These issues will be strongly related to the planned capacity of the installation. The proximity of the grid system to the site itself is also important as it will have a significant impact on cost. All of these issues will require detailed interaction between the operating organization and the grid owner.

4.5.2.2. Use

These factors can be used as an avoidance criterion in stage 1 to eliminate areas and sites where the costs of installing suitable grid infrastructure would be prohibitively expensive. It will also be used in selecting and ranking sites based on detailed grid analysis and estimates of the costs of any grid enhancements.

4.5.3. Location of major load centres and selling price

4.5.3.1. The issues

Nuclear power plants should be located relatively close to major load centres (large populations, energy intensive industries, industrial centres) in order to minimize the cost of transmission lines and power losses. (This requirement needs to be balanced with the safety related criteria related to distance from large population centres).

The selling price of electricity may also vary within the country and the overall value of the electricity supplied will need to be taken into account. This will involve quantifying projected market prices for the energy produced by a prospective NPP, taking into account key drivers of power prices over the plant’s operating life and assessing comparative economics for the candidate sites. Some of the input will depend on perception of impact and value rather than factual data and such studies need to be conducted and reviewed with care.

4.5.3.2. Use

These factors will mainly be used in screening and ranking sites based on the cost differentials of the different sites.

4.5.4. Suitability of transport infrastructure

4.5.4.1. The issues

Transportation of large and heavy equipment from the port/manufacturing units to the site is an important aspect. The distance, loading capacity of roads/bridges, curvatures, clearances and slopes on the route, availability of rail networks have to be studied with respect to the sizes and weights of equipment. Many of these issues can be avoided if site accessibility with vessels is assured. The river/canal or sea routes and coasts have to be studied for key issues such as limitations due to bridges, existing harbours capacities or possibility to construct suitable harbours.

The steam generator was previously the heaviest and longest item equipment in a NPP. However, with the current latest trend of modularization in construction, which reduces construction time and costs, the size and weight of the equipment that needs to be transported to the site has increased. The latest ABWR now has over 200 modules per unit, with the largest weighing up to 940 t. An important issue is not just the NPP equipment, but also the construction machinery, notably the cranes that can lift very heavy loads (VHL). VHL cranes now have capacities of up to 1200 t modules/components at a 40 m radius and a height of 60 m.

The possibility of ship transport for such machinery and equipment to the site offers significant advantages, but rail transport is also capable of transporting heavy loads, though with a size limitation. Road transport is usually the most restrictive method for equipment delivery.

The transportation of nuclear fuel and nuclear waste also has to be considered.

4.5.4.2. Use

These factors may be used at all stages of the process. Some sites will be ‘inaccessible’ due to local geography. The costs and social impact of providing suitable transportation routes will certainly be factors in screening and ranking sites.

4.5.5. Technology considerations

4.5.5.1. The issues

The total capacity of all the planned NPPs at one site is an important factor in the siting review. Different sites will have different capabilities with respect to grid and cooling. Market supply may require load following, which in turn will require technologies (such as boron control) that need environmental dilution capacity. Some sites may be very suitable for a smaller output plant but unable to support the larger NPPs. Different designs also have different capabilities to withstand hazards although in general it will be a question of the cost of designing to withstand the hazard and the effect on insurance costs, rather than a factor that will determine the need for a particular reactor type. The safety issues related to these hazards are mentioned in Sub-section 4.4.1 and addressed in the IAEA Safety Requirements and Guides [2–6].

For a country with a large seismic hazard, the basic structure of the design, and its seismic response, is a key factor.

4.5.5.2. Use

Technology considerations are not so much a criterion as data to be put into a siting study which may be used at all stages of the selection process. The costs related to the required improvement in the reactor type (for example to address seismic or flooding) will certainly be a factor in screening and ranking sites.

4.5.6. Impact of existing facilities

4.5.6.1. The issues

The design of a proposed nuclear power plant close to an existing facility offers significant construction, operation and maintenance benefits in the use of services already in place. However, there will also be a number of constraints imposed by the host facility, such as sufficient distance of large cranes from existing security fences to avoid damage if the crane topples. The nuclear power plant licensing will have to consider the existing environmental permits, and may have to consider plans for removal, containment and monitoring of hydrocarbon contamination at the proposed site.

Environmental cleanup or remediation costs incurred in developing industrial sites need to be considered.

4.5.6.2. Use

These factors will mainly be used in screening and ranking sites based on the cost differentials of the different sites.

4.5.7. Site development and construction costs

4.5.7.1. The issues

The impact of the choice of site on construction costs and the site development costs, depends on a number of factors that are listed below.

- Availability of industrial infrastructure: The availability of industrial centres in the vicinity has many advantages; including the availability of a supply chain, facilities for minor repair work and provision of non-specialist parts during construction and operation. Moreover, it provides a load centre at close distance;
- Availability of labour: A huge labour force is required during the construction of a NPP. Availability of local skilled and unskilled labour at reasonable rates at a site is therefore an advantage;
- Services and construction material availability: The site will require a suitable supply of electricity for construction purposes and heating/cooling for the site facilities etc. and will require appropriate telecommunications. During the construction of a NPP, huge quantities of aggregates and cement will be needed. Availability in the vicinity of a site helps to reduce transportation costs. Adequate freshwater quantities for the construction must also be available. Typical freshwater requirements would include measures during excavation (up to 40 thousand m^3/d), cement mixing and subsequent cleaning and flushing (up to 120 thousand m^3/d), and drinking water for the construction village (up to 600 thousand m^3/d);
- Land available for construction: Availability of land for the proposed number of units, together with auxiliary facilities, obviously has to be considered. However, a considerably larger area is required during the construction of the plant. In the case of modular construction, an even larger area of several hectares can be required for storage, prefabrication and pre-assembly of modules. Moreover, larger areas around a NPP are required in some States to ensure better control on the exclusion area boundary;
- Site topography and land characteristics: The presence of nearby mountains or steep terrain has a large impact on the costs associated with earth moving activities. Steep slopes can also be unstable and produce damage to safety related facilities because of landslides. On the other hand there can be security and safety benefits (e.g. likelihood of aircraft crash). The sites must also be investigated for the presence of large scale topographic features that cannot be relocated or altered; such as stream channels, deep incised valleys, knobs, sinkholes, abandoned mines, etc. Hard rock sites with irregular topography and very soft soils require huge cut/fill operations and result in increased costs of preparatory work. There may also be land remediation/preparation costs. Furthermore, site topography is related to security threats and such aspects are also important during the site selection and assessment phases;

— Land cost: The cost of land varies from one region to another. In some cases it may be necessary to purchase additional land for a town with all the suitable facilities to support the workforce, if there are no existing facilities in the vicinity. It may also be necessary to purchase land in other areas for grid enhancements, transportation arrangements etc. It may also be necessary to provide compensation (financial or provision of other land areas) for land of special interest;
— Climate: In some regions, snow accumulation on building roofs can increase the design load. Snow on the plant site can also impact drainage, which could cause flooding. Additionally, it would be prudent to investigate the potential for changes in the site's suitability in relation to the general global warming issues. These would include: changing patterns of winds and ocean currents, air and water temperatures, height of tides and floods, severity of storms, varying levels of rain and snowfall, etc. that may or may not have further significance in selecting and evaluating sites. The additional costs required to address these issues is a factor to be taken into account.

4.5.7.2. Use

These factors may be used at all stages of the process, for example to rule out national parks or areas of special interest. The costs of acquiring adequate land and developing the construction site will certainly be a factor in screening and ranking sites and detailed cost analysis will be required. Evaluating the site development costs for potential new nuclear generation requires a quantitative approach to ranking sites through a detailed cost analysis.

4.5.8. Multi-unit sites

4.5.8.1. The issues

There are a number of advantages to locating multiple units at a single site. Built in series allows costs of construction and associated infrastructure to be shared between units. The cost of site studies per unit is also reduced. Depending on the phasing, it allows the construction teams to move from one unit to the next. Similarly, during operation, maintenance outages can be scheduled to minimize the costs as well as supply disruption. It also only requires a single programme of stakeholder involvement and approvals to enable multiple units.

Obviously all the other factors, e.g. cooling water supply need to be assessed against the increased size of the facilities. Equally the impact of the generating capacity being at the same point on the grid needs to be considered and there may be some specific stakeholder issues associated with using a single site for multiple units.

4.5.8.2. Use

These factors will mainly be used in screening and ranking sites. Vendors and project management organizations should be able to provide information on cost savings. Analysis of grid capability will need to be carried out. Stakeholder issues will rely on local and national knowledge of opinion formers and decision makers.

4.5.9. Physical security and protection considerations

4.5.9.1. The issues

The security of the nuclear facilities is an important criterion for site selection and for establishing plant configuration and plant operational procedures. Plant security is ensured primarily through features that are built into the strength of the structures, configuration of the systems and layout of the buildings, and barriers and security systems which are set up to restrict access and entry into the plant. Any new nuclear power station must achieve the necessary level of security protection irrespective of its location. However, physical protection design requirements are influenced by the site location. For example, NPPs located in a remote area bordered by a small population density may require different physical protection measures to those that apply to NPPs located near a large urban area. It is necessary to consider the physical dimensions of the NPP and its surrounding environment, including:

— The topology of the area which can impact the overall security barrier design (such as line of sight view);
— The proximity of other facilities or services that could adversely affect physical protection, such as a chemical plant that could release a noxious substance, a hydroelectric dam that could be accidentally or deliberately breached, or an airport that provides significant flight traffic in the vicinity of the site;
— Site boundaries;
— Adverse weather that could be a potential impediment to the operability of physical protection systems;
— Details pertaining to the establishment of a construction site, such as the positioning of perimeter fences, access and egress points.

Operating organizations are required to produce site security plans that are submitted to the competent regulatory body for approval. The final security measure is through the regional and national security agencies that monitor the potential sources of threat against the critical facilities such as nuclear power plants and devise and implement plans and procedures to counter them.

4.5.9.2. Use

These factors may be used at all stages of the selection process. Some sites may be ‘unacceptable’ from a security point of view. The costs of providing suitable security will certainly be a factor in screening and ranking sites.

4.5.10. Stakeholder opinion

4.5.10.1. The issues

As explained in Section 3, involvement of local and national stakeholders is essential, right from the beginning of the siting process. However, the likely stakeholder support for a NPP may vary between the sites being considered. Local citizens and NGOs may influence the regulatory bodies which can in turn place impediments in the approval process, or discourage investors or effect costs.

4.5.10.2. Use

These will mainly be used in screening and ranking sites. The relative ranking of sites based on stakeholder opinion will be largely subjective but it is important to ensure that the judgements are made by those competent and well informed on local and national issues.

4.5.11. Regional regulatory and legal processes

4.5.11.1. The issues

Potential sites may have regulations which are specific to the local area or region. They may also be subject to various national and international agreements that may prohibit a NPP, or can complicate the approval, construction, operation or decommissioning. The process for securing approvals may also vary and have different durations.

It will also be necessary to interact with other non-nuclear governmental organizations or agencies, whose activities or decisions may affect the cost and timescales of the project. It is important to have an overview of legal processes that may vary between sites.

4.5.11.2. Use

These factors will be used in the first stage of the process to eliminate sites that preclude NPPs due to regulatory reasons. The simplicity of the legal procedure for siting the facility will mainly be used in screening and ranking analysis. The relative ranking of sites based on these issues will be largely subjective, though there may be historical information on the length and difficulty of planning and construction approvals. It is important to ensure that the judgments are made by those competent and well informed on local and national issues.

4.6. SOCIO-ECONOMIC FACTORS

As the nuclear facility requires a substantial work force for construction and operation, as well as considerable finances, it will inevitably have an important socio-economic impact. There are positive and negative aspects and these are discussed in detail in the following sections.

In addressing socio-economic factors, special emphasis may need to be given to communities “that possess notably distinctive cultural character; i.e. towns that have preserved or restored numerous places of historic interest, have specialized in an unusual industry or a vocational activity, or have otherwise markedly distinguished themselves from other communities.”

Detailed stakeholder involvement issues are dealt with in Section 6 of this publication.

4.6.1. Future land use planning and sites ownership

4.6.1.1. The issues

The suitability of the planned development of the area with the construction of a nuclear power plant needs to be considered. Ownership of the land is also a factor, particularly if some relevant areas and sites belong to the Government.

Construction of the NPP will also impose controls on the future developments of nearby land (e.g. dam construction).

Some areas may be designated as of scenic value or cultural heritage. Historic buildings and fortifications are an important cultural asset and are often associated with tourism.

4.6.1.2. Use

These factors will mainly be used in screening and ranking sites.

4.6.2. Regional economy

4.6.2.1. The issues

The factors to be considered here are not related to project cost but to the project’s impact on the economy of the region.

There are likely to be positive impacts, such as economic development opportunities and improvements to local infrastructure and community services such as fire, police, utilities, health care, education, recreation and transportation. These are likely to be required and funded through additional tax revenues.

Locating the NPP in an area that allows for the waste heat to be used for various industrial purposes or residential heating systems will not only increase the profitability of the plant itself, but will also provide cheap energy to the local communities and industries (in addition to lower environmental impact due to thermal discharges).

The NPP will also have an economic effect through the labour market, providing employment for various skilled workforce groups. In addition to increased income revenues and energy available for development, there will also be indirect effects such as increased knowledge, competitiveness and quality of the local industry.

If the site is in a region that has compatible industrial activity, there will probably be a significant amount of skilled workforce available for the facility’s construction and operation. The NPP would provide an increase in revenues for the local industries and it would minimize possible migration and developmental issues.

A regional development plan needs to be developed, addressing the energy demand projections in the near future as well as the land use, thus indicating the economic growth, the role of the provided energy (electricity or heat) and the secondary economic benefits. Advantage should be given to those areas that have development plans in place. Selecting a site in such an area would allow the economic impact of the nuclear power plant to be maximized. The ease of planning applications and compensation costs, and local taxes for using sites will also depend on development opportunities.

There may also be negative economic impacts of the NPP. The economy of the region may be predominantly based on non-industrial services (e.g. tourism, aquaculture, agriculture) in which case the nuclear facility may (but not necessarily) result in degrading the visual and aesthetic character of the area around the site, changing the aquatic conditions or industrializing the area. The financial (or political) value of the existing economic activities may be substantial, precluding industrial development.

4.6.2.2. Use

These factors will mainly be used in screening and ranking sites based on the cost differentials of the different sites. Information will be available from local and regional governmental bodies. Some of the factors will depend on perception of impact and value rather than factual data and such studies need to be conducted and reviewed with care.

4.6.3. Local society

4.6.3.1. The issues

NPPs require a significant workforce throughout their life cycle and some of it will probably need to be imported from other areas/regions. The economic benefits and possible industrial development near the NPP may attract additional workers. The sites may differ in the level of expertise and knowledge that can be supplied to the NPP. The social fabric of the area, if it is relatively isolated, may be strained or altered by the sudden influx of a significant number of non-local people. There will be impacts on local infrastructure and community services. Availability of professional staff and capital through taxes paid by the NPP may also change patterns of behaviour. The ability of the social infrastructure around the site to withstand the impact will vary. Another important factor will be environmental justice; if socially and financially less capable groups are not positively affected by the project it may be rejected.

The site may be in the vicinity of special cultural hot spots. These include areas of archaeological interest, historical or cultural value; etc. Although they might not be inhabited, they usually involve tourist and scientific activities, and their protection is highly regarded in society. NPP location in those sites are not likely to be acceptable.

The existence of local colleges, trade schools, and other training facilities near to the site also needs to be evaluated. If the area does not have sufficient capacities for training, this may increase the cost, and bring environmental concerns.

4.6.3.2. Use

These factors will mainly be used in screening and ranking based on the differing impacts on the sites, although social disturbance impact may be used in Stage 1 as exclusion or avoidance criteria. Most of the factors under this heading will include subjective judgements based on knowledge of the area demographics.

4.6.4. Landscape

4.6.4.1. The issues

Landscape effects involve changes to individual landscape elements and characteristics, and the consequential effect on landscape character. This also includes the close in area of sea where there is shared inter-visibility between land and sea. The coastal landscape includes areas of significant heritage and scenic value and provides an important recreational resource. Visual impact assessment is concerned with the impacts of the development on views of the landscape through intrusion, obstruction or changing the content or focus of views.

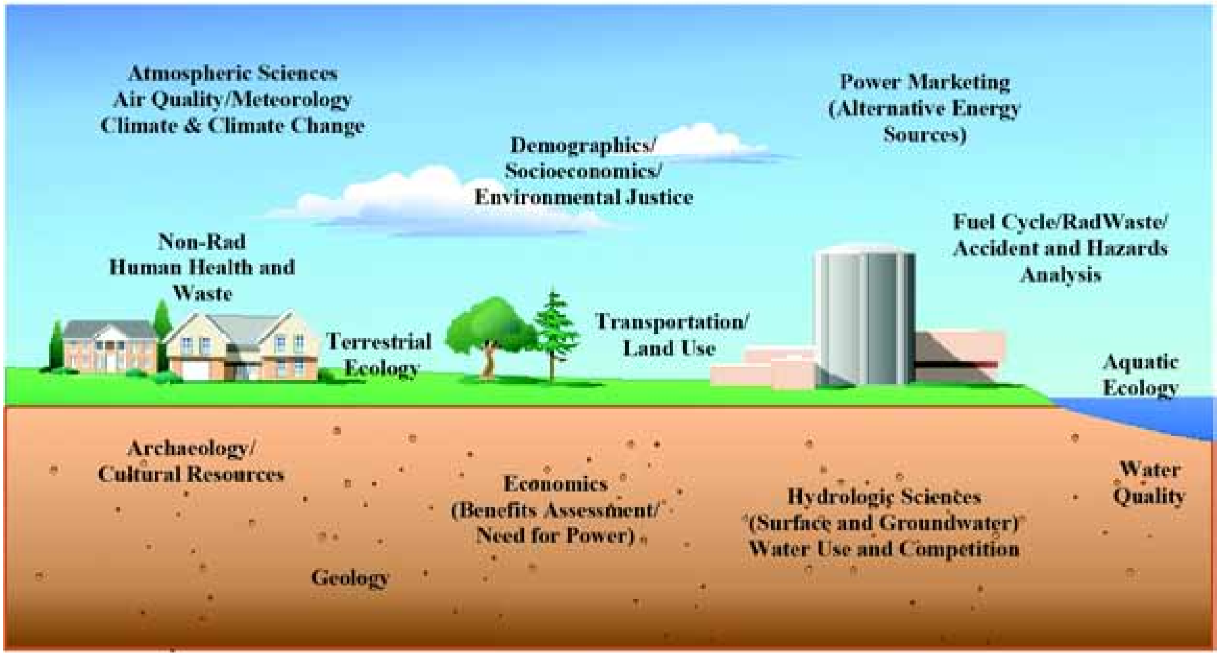

FIG. 6. Environmental considerations on siting.

Changes in landscape and seascape may have an adverse impact not just on tourism and recreational activities, but on the general public's opinion on the project's acceptance. Clearance of the site will inevitably have an impact on existing landscape features and habitat. A substantial amount of construction could be involved and is likely to have implications on views of the surrounding area. The construction work itself may be more visible from the surrounding area in the short term than the finished development. Tower cranes will be used to lift and position elements of the buildings into place and this clearly affects the landscape during construction.

There is a potential for night time visual impacts from the lighting associated with the development.

4.6.4.2. Use

These factors will mainly be used in screening and ranking analysis.

4.6.5. Noise

4.6.5.1. The issues

Obviously the construction of a NPP will involve considerable additional noise but this will in general be common for all sites and not a particularly important issue for site selection. However, if the site will require significant blasting activities or if the site has particularly unhelpful sound characteristics or has sensitive areas nearby, noise may be a relevant factor.

4.6.5.2. Use

These factors will mainly be used in screening and ranking analysis.

4.7. ENVIRONMENTAL CONSIDERATIONS

The siting process for nuclear power plants will be strongly influenced by specific environmental considerations for the regions or sites of interest illustrated in Fig. 6. These considerations typically involve the protection of air, water, wildlife, and cultural resources. In terms of complexity and duration, obtaining the necessary environmental permits may differ considerably for various sites. Therefore, finding a site with less environmental concerns will not only shorten the permitting process, but it will also reduce the construction and operation costs.

The environmental factors need to recognize that environmental considerations differ in magnitude and scope between construction and operation. It is also necessary to establish an environmental characteristics baseline for all of the issues in order to be able to carry out an impact assessment.

This section only addresses the potential non-radiological environmental impacts. All issues related to the radioactive releases are dealt with in the IAEA Safety Guides.

4.7.1. General eco-system characteristics

Two major effects will influence the site's suitability to the environmental criteria, namely the impact on key species and the impact on ecosystems; this section discusses these two effects. Sub-sections 4.7.2–4.7.5 discuss the pathways and factors that influence the impact; such as water, land, etc.

4.7.1.1. Presence of protected and migratory species

Species may have a commercial, cultural or supporting value. Commercial species are important for the fishing industry and their disruption will have an impact on it. Disruption of species with cultural value or flagship species can affect the tourist industry, but it may also promote a negative reaction to the project by the public. Species that support the previous two types should also be taken into consideration as their disruption will directly affect the species with cultural and commercial value.

The IUCN categorization for species populations should be used to provide a more detailed picture: critically endangered, endangered, vulnerable, near threatened and least concern.

Presence of species that are characterized critically endangered or endangered should be used as exclusion criteria.

Presence of species that are characterized as vulnerable or near threatened should be used as avoidance criteria[1].

Special attention should be given to avoidance of habitat fragmentation. A species depends on enough individuals to maintain its genetic diversity, as well as on access to feeding, breeding or wintering areas. Threatened and endemic species are particularly of interest in such cases since fragmentation can lead to declining population size.

Areas where the habitat fragmentation is likely to increase the status for the species to a more threatened level should be avoided if possible. However, solutions can be implemented with varying costs.

4.7.1.2. Site's ecosystem sensitivity and value

The ecosystem of the region where a potential site is identified may be under various protection levels and standards such as: national parks, RAMSAR convention sites, biosphere reserves, special conservation and protection areas (e.g. Natura 2000) and other systems of global significance.

Conservation areas preclude siting nuclear facilities and represent exclusion criteria.

Protected areas for unique and rare ecosystems are to be used as avoidance criteria. Involving various levels of protection, sites in protected zones would complicate the NPP siting process.

The potential candidate site may be located in an ecosystem that has an abundance of species: migratory, endemic, protected, etc. making it a biodiversity hotspot and thus of special interest to the public and scientific community. Various indexes, such as Shannon or/and Simpson diversity indexes may be used to indicate the

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[1] Characterizing the presence of 'vulnerable' species as an avoidance rather than exclusion criterion is based on the fact that NPPs can have a beneficial impact on those species. As an example, Turkey Point nuclear power plant has played a crucial role in saving the endangered American crocodile (*crocodylus acutus*), providing breeding ground for the crocodiles, thanks to its cooling system. The reptiles prefer the plant's cooling water canals because the constant water level within the system eliminates the problem of nest flooding and protects the nest from predators. Turkey Point has become home to one-quarter of the USA's entire population of American crocodiles {WNN, 27 July 2007}.

ecosystem's biodiversity value. Higher biodiversity indexes can be used as avoidance criteria for siting a nuclear facility.

Some ecosystems are less robust than others. They can be based on so-called key species (e.g. corals or mangroves) or can have a very delicate balance among its living and non-living constituents, with very low tolerances to (further) disruptions (e.g. ecosystems already under pollution stress).

Sensitivity of an ecosystem can be indicated through three factors regarding the key species (species of interest):

(i) The ratio between the expected area of impact with its carrying capacity compared to the Area of Occupancy (AOO);
(ii) The recoverability of the species of interest from the expected impact (<1yr; <5yr; <10yr; <25yr; >25yr);
(iii) The possibility to mitigate the adverse impacts of the nuclear facility on the ecosystem by habitat restoration in an adjacent area equal to the losses due to disruption, or to establish natural reserves that would compensate with their biological productivity.

4.7.2. Aquatic ecology and marine impact

4.7.2.1. The issues

The marine environment is an important resource not only in terms of the biodiversity it supports but also as a resource for various activities such as tourism, recreation and fishing. Therefore, the quality of the marine environment not only has ecological consequences but also a socio-economic impact as it contributes to the quality of people's lives.

(i) During construction the key issues are the disruption of species by activities such as dredging; disturbing the bottom sediment. The impact due to dredging will depend on the extent to which the bottom sediment is contaminated by any harmful chemicals as well as by the grain size of the sediment, and the combination with the coastal currents. Silt and clay, in addition to their potential to keep pollutants in their porous structure, can require longer time to settle and can be deposited on a substantially larger area, with adverse impacts on ecosystems. Coastal sediment properties can be used as avoidance and suitability criteria, since engineering solutions may be provided.
(ii) During operation, sedimentation may also be an issue. Additionally, the impact of the thermal discharge from cooling water needs to be considered. Higher water temperatures may have positive consequences (e.g. faster hatching, more food) as well as negative (e.g. algal blooms, species migration from the impact area). The impact on the water quality must also be assessed against the limits of the ecosystem or the regulatory limits. Also, another important factor is the effect of entrainment/impingement, since large quantities of water used for cooling may contain fish eggs, larvae, plankton, fish and other organisms.

The species of interest in the aquatic environments can be, benthic, nektic and/or planktonic. Each of these can provide a suitable bio-indicator for the impacts that may occur since in many cases they represent the basis for the whole habitat. Such is the case with corals or sea grass, providing food and shelter for many species on the bottom of the food chain.

Depending on the PPE specified temperatures of effluents from the NPP, sites with thermal threshold of the receiving ecosystem lower than the discharge heat load should be excluded. Areas used for breeding and nursing of aquatic organisms, should be excluded. Areas of high primary production should be avoided for water withdrawal or discharge.

4.7.2.2. Use

These criteria may be used at all stages of the selection process. The impact on the aquatic environment at each site will certainly be a factor in screening and ranking sites. Assessing the impacts of the power plant upon the marine environment, specifically, marine ecology, habitats and geomorphology is an important factor for ranking sites.

4.7.3. Terrestrial ecology

4.7.3.1. The issues

During construction, the key issues relate to the loss of land (including roads, support facilities, etc.) with an important ecological value (e.g. wetlands). Furthermore, the potential need to dewater the site can cause an impact to the neighbouring area through groundwater disturbance.

During operation, the use of cooling towers to discard of the excess heat and the subsequent emissions of steam can result in changes to the microclimate (see section on air quality). This may primarily have an impact on the vegetation cover around the site, with resulting impacts on the whole local ecosystem. It is also important to consider the closeness of nearby important species that might be affected by light, noise and electro-magnetic fields as well from the transmission lines (e.g. some avian species), or long term fragmentation of habitat.

4.7.3.2. Use

These factors may be used at all stages of the selection process, for example to rule out areas of protected wetlands or areas inhabited by protected species. The screening and ranking should take into account the sensitivity of the ecosystems and the magnitude of the impact on the species of interest.

4.7.4. Freshwater impact

4.7.4.1. The issues

The impact of the NPP plant upon the freshwater environment, specifically, surface water and groundwater is an important factor for consideration. A desalination plant or/and a demineralisation unit may be needed to reduce the volume of freshwater needed, thus increasing the cost of the NPP.

Considering the possible uncontrolled releases into the ground, either in construction or in operation, aquifer vulnerability will vary based on the protective layer soil type and depth. Provided that the aquifers are meaningful in size and use, they can be used as a siting criterion, with the following classification:

- Aquifers with extremely high and high vulnerability should be excluded;
- Aquifers with moderate and low vulnerability should be avoided;
- Aquifers with extremely low vulnerability should be deemed suitable from the perspective of siting nuclear power plants.

4.7.4.2. Use

These factors may be used at all stages of the process. The regional analysis will focus on the application of exclusion criteria. The impact on the freshwater environment at each site will certainly be a factor in screening and ranking sites.

4.7.5. Air quality

4.7.5.1. The issues

During construction, aerial impacts originate mainly from dust from the site area and the movement of vehicles, as well as odours and emissions of various gases from transport and operation of the construction machinery.

Operation related impacts on the air quality from nuclear facilities are usually related to the transport from and to the site and the testing and operation of the backup diesel generators. However, additional impacts may be caused by the NPP’s wet cooling towers, should they be used. The drift caused by them may impact the visibility, humidity and temperature of the air in the neighbouring areas. Where wet cooling towers are used at coastal sites, emissions of salt in the air might impair the aerial quality below the level that the ecosystem can support.

4.7.5.2. Use

These factors are applied mainly when wet cooling towers are foreseen for the nuclear power plant. They may be used in screening and ranking analysis.

5. METHODOLOGY FOR SITING STUDIES

This section describes a multi-stage process for selecting potential sites for NPPs. A summary of the process was shown in Fig. 1 and a more detailed pictorial representation of the process and terminology is shown in Fig. 4 at the end of this section.

Before initiating a siting project, it will be necessary to identify the Plant Parameter Envelope as discussed in Sub-section 4.3.

5.1. STAGE 1: SITE SURVEY

5.1.1. Purpose

The aim of the first stage is to identify some criteria, based on the factors described in Section 4 that can be easily applied and will reduce significantly the number of sites needing detailed investigation. It is not possible to define exactly which factors should be used for this as it will depend on the region of interest. However, it is important to identify the right criteria that will reduce the number of sites to a manageable number. These criteria are often not absolute but represent a judgement as to what is the most appropriate acceptability threshold for the local situation.

5.1.2. General considerations

The areas are first screened using exclusionary criteria to eliminate those areas in which it is not feasible to site a nuclear power facility due to regulatory, institutional, facility design, social or environmental constraints. Examples of criteria that will often be used at this stage are: inadequate cooling water, surface faulting or seismic regions, major flooding, population density, volcanic activity, national parks.

Further screening is performed using avoidance criteria to eliminate feasible, but less favourable, areas. Should this process result in an area too small for identification of an adequate number of potential sites, the avoidance criteria can be relaxed and the process repeated.

Equally, at this stage, a large number of potential sites may have been identified and some high level screening, using suitability criteria, may then be appropriate to reduce the number of sites for further investigation. Many requirements can be met at a cost, but they may be included in this stage if the cost of meeting the requirement would clearly be excessive compared to other sites and the necessary data are readily available.

If earlier studies of this nature have already been carried out, but then put on hold, the key requirements of this stage are to:

(i) Review and update the data, criteria and methodology of previous studies;
(ii) Identify new potential sites and areas;
(iii) Select potential sites using the latest and updated criteria and methodology.

Some countries may have carried out these studies some time ago, in order to select earlier sites for nuclear installations. If these sites have space for additional units, it may be clear to those responsible, that building on these existing sites is the best approach and that a complete reassessment is not necessary. Nevertheless, some

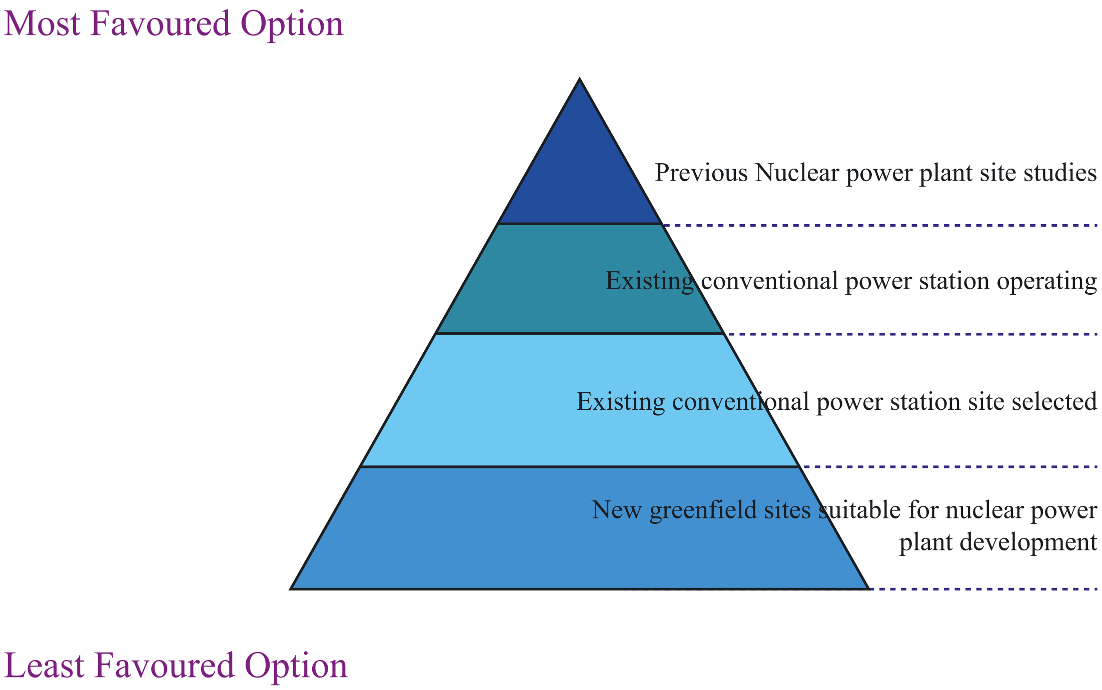


FIG. 7. Site survey approach.

consideration needs to be given to this part of the process in order to justify the decision and to demonstrate that there is not now a better site.

An example of an approach that has been used was to look for potential sites, using the hierarchy illustrated in Fig. 7.

5.1.3. Output

The outcome of this stage of the process is the identification of candidate sites. Such sites should be a few square kilometres, somewhat larger than that required for the eventual site, in order to allow the eventual precise optimal site to be determined. The site also needs to include adequate room for construction activities.

5.2. STAGE 2: SITE SELECTION (ADDITIONAL SCREENING ANALYSIS AND RANKING ANALYSIS)

The output from Stage 1 may well leave a significant number of sites. The site selection stage may therefore be divided into two steps, additional screening analysis followed by ranking analysis. The first step is to eliminate some of the sites, again using information that is readily available, or relatively simple to obtain. The second step (ranking analysis) is then to evaluate the remaining sites in more detail using the majority of the criteria from Section 4, weighted according to their significance. In practise it may well be necessary to iterate and repeat certain parts of the process.

5.2.1. Step 1 — Additional screening analysis

5.2.1.1. Purpose

The purpose of this step is to reduce the number of candidate sites to a few (less than 10) that can then be analysed in detail to identify selected sites ranked in order. If there are only a few sites, then it is possible to move directly to step 2. This step should include all criteria that are likely to help reduce the number of candidate sites and for which some data is readily available. Methods include rejecting sites based on certain criteria or ordering sites based on certain criteria and identifying those sites that are more frequently highly ranked.

5.2.1.2. General considerations

Screening is conducted as an iterative process with the application of refined criteria until an appropriate number of candidate sites can be identified. A key difference compared to the application of criteria in Stage 1, is the introduction of data that is at a more refined scale, whilst avoiding excessive investigations of a large number of sites.

Potential techniques include:

— Suitability scaling — Where for each criteria the site is simply ascribed a 'yes' or 'no'. This is a simple method that will reject some sites;
— Ordinal scaling — This method seeks to put the sites in an order of preference based on readily available information. Care must be taken in comparing results for different criteria as the relative order does not indicate whether all the sites are similar or whether there are large differences between some sites;
— Interval scaling — A development of the above method is to give a 'value' for each criteria and each site which reflects the judgement of its suitability. For example, the volume of soil that needs to be removed to make a site suitable could be used as the basis of ascribing a value between 0 and 5.

It must be remembered that although the methodology described here is based on quantitative values, they are only estimates based on readily available information. The values are only used as an aid to judgement and the uncertainty of the data must be recognized.

5.2.1.3. Output

The output of this step is a reduced list of candidate sites but not in any particular order of priority.

5.2.2. Step 2 — Ranking analysis

5.2.2.1. Purpose

The purpose of this step is to identify and rank a relatively small number of sites using a more detailed study. This is principally performed using a series of suitability criteria based on published data and reconnaissance level information. There may be a need for some limited site specific work such as geophysical profiles or boreholes (for example to demonstrate that there are no capable faults in the site area).

5.2.2.2. General considerations

There are several alternative methods for ranking candidate sites to arrive at the list of the selected sites. It is particularly important that this part of the process is transparent and linked with a well-developed stakeholder involvement plan. Further information is provided in Section 6.

There are two important parts to the ranking analysis. Firstly defining the list of actual criteria that will be used and secondly 'scoring' the sites in some way against the criteria. With respect to the second, there are a number of methods. One approach is to use the differential cost that would be required to make each site equal and seek to minimize this parameter. Other methods consider weighting factors for various attributes of the site. These tend to become subjective but do allow all factors to be considered. It provides a mechanism to take account of the 'value' of each criterion, even though it may be difficult to quantify in monetary terms, for example some environmental impacts or effects on national heritage.

This methodology also allows different weightings to be considered in order to see the sensitivity of particular factors to the overall decision. No specific methodology is described here as there are a number of tools available for decision analysis in the open literature.

Assignment of weights is a sensitive issue in siting studies because the opinions and value judgments as to the relative importance of individual criteria vary depending on the perspectives of the individual stakeholder or group (e.g. operating organization, regulator, and public interest group).

Some additional detail on ranking analysis is provided in Appendix I.

5.2.2.3. Output

The output of this stage is a list of preferred candidate sites ranked in order of overall preference against the siting criteria.

5.3. STAGE 3: SITE ASSESSMENT

5.3.1. Purpose

The purpose of this stage is to confirm the acceptability, complete the characterization of the selected site and develop/finalize an Environmental Impact Assessment (EIA) study for the selected site.

5.3.2. General considerations

The assessment of the site will require a wide range of technical activities including:

- Field observation, exploration, testing, measurement and monitoring;
- Data analyses and calculations related to hydrology, geology, seismology and seismic hazard, geotechnical, meteorology and air quality assessment, radiological analysis, emergency planning, security, ecology and radioecology.

The site assessment process for nuclear installations is an important part of the licensing process.

For those criteria that are not safety related, the purpose of the site assessment phase is to provide adequate confidence that the design basis performance and cost assumptions will be met for the site. The operating organization will need to provide the vendor adequate assurance that the site has the required characteristics. This will require site investigations, monitoring and analysis and the operating organization should discuss how this will be carried out with potential vendors to ensure that an adequate site evaluation report is prepared.

For a potential site within an existing industrial facility, it is also necessary to establish the following:

- History of site use;
- Current physical, geotechnical, hydro-geologic, climatologic, ecologic and sociologic conditions;
- Site infrastructure — availability of utilities such as electrical power (for both import and export), plant/instrument air and inert gases, process water, storm water collection and drainage, wastewater treatment and discharge, solid and hazardous waste management and disposal, fire protection, security, and worker health and safety;
- Facility and site access via highway, railroad and maritime vessels;
- Listing of existing applicable permits and agreements with local, municipal, state, federal and international agencies;
- Reports of site investigations indicating the known and expected types, concentrations and extent of potential hydrocarbon contamination at the site;
- Identification of onsite burial or disposal areas.

5.4. STAGE 4: PRE-OPERATIONAL

5.4.1. Purpose

The first step of this stage is for the operating organization to formally confirm the acceptability of the site and to request a permit from the relevant regulatory authorities. There is then a need to prepare the site, including the setting up of equipment needed for ongoing monitoring of the site.

5.4.2. General considerations

The output from the previous stage of the process (site assessment) is the Site Evaluation Report (SER) that will be used to confirm acceptability of the site by the operating organization of the NPP. This document would be subsequently divided into appropriate sections for submission to relevant regulatory bodies. It therefore includes considerations related to:

- Safety;
- Security and safeguard;
- Emergency plans;
- Environmental impact;
- Socio-economy;
- Quality assurance/quality management programme including data management programme;
- Engineering and cost;
- Legal;
- Site infrastructures etc.

Site preparation by the owner entails the removal of contaminated soils and water and the preparation of boundaries which will define long term responsibilities regarding waste disposition. If there is any pre-existing site contamination, this will need to be removed and/or immobilized by creating physical non-permeable horizontal and vertical boundaries. Mechanisms will also be required to support future monitoring of contamination and ultimate removal of material in support of decommissioning. Environmental monitoring of the site and surrounding area may be needed during this period to clarify the baseline condition for beginning project site preparation work.

Project site preparation entails the management of the site boundary by the operating organization in order to support its obligations to contain any effects of construction, operations and decommissioning within agreed boundaries. If an excavated site with new or existing barriers is provided, then the project site preparation scope will include bringing in suitable replacement soils, possibly installing a separate groundwater monitoring system on the project side of the barrier(s), and allowing sufficient room between foundations and agreed boundaries so that decommissioning work can be completed without disruption to boundaries.

5.5. STAGE 5: OPERATIONAL

There is an ongoing requirement to monitor site characteristics to ensure safety case assumptions remain valid. A periodic safety review will need to provide results of site monitoring. It is also necessary to control other construction activities that may have an impact on site aspects of the safety case.

At the expiration of the operating license, the owner is responsible for decommissioning the plant. Some countries may require that a decommissioning plan is developed during the construction of the plant and the site characteristics and requirements for the site after decommissioning will be part of this plan.

5.6. THE OVERALL PROCESS

While the description of the siting process is described in Fig. 6, a pictorial representation of an example of the whole siting procedure is summarized in Table 2.

The example of the *siting procedure* provides an up to date framework for the site selection process. The different steps of the siting process are areal in nature; screening of a relatively large region of interest is performed to identify a number of discrete ‘site-sized’ parcels for evaluation as a potential nuclear power facility site. These steps are accomplished using mappable information. Comparing individual sites based on their relative suitability is the focus of steps 3 and 4. This portion of the process begins with the use of mapped and other published information and concludes with detailed information collected through on-site investigations, as necessary. Step 4 culminates in selecting a preferred site, thus enabling to initiate the relevant site evaluation for the preferred site(s).

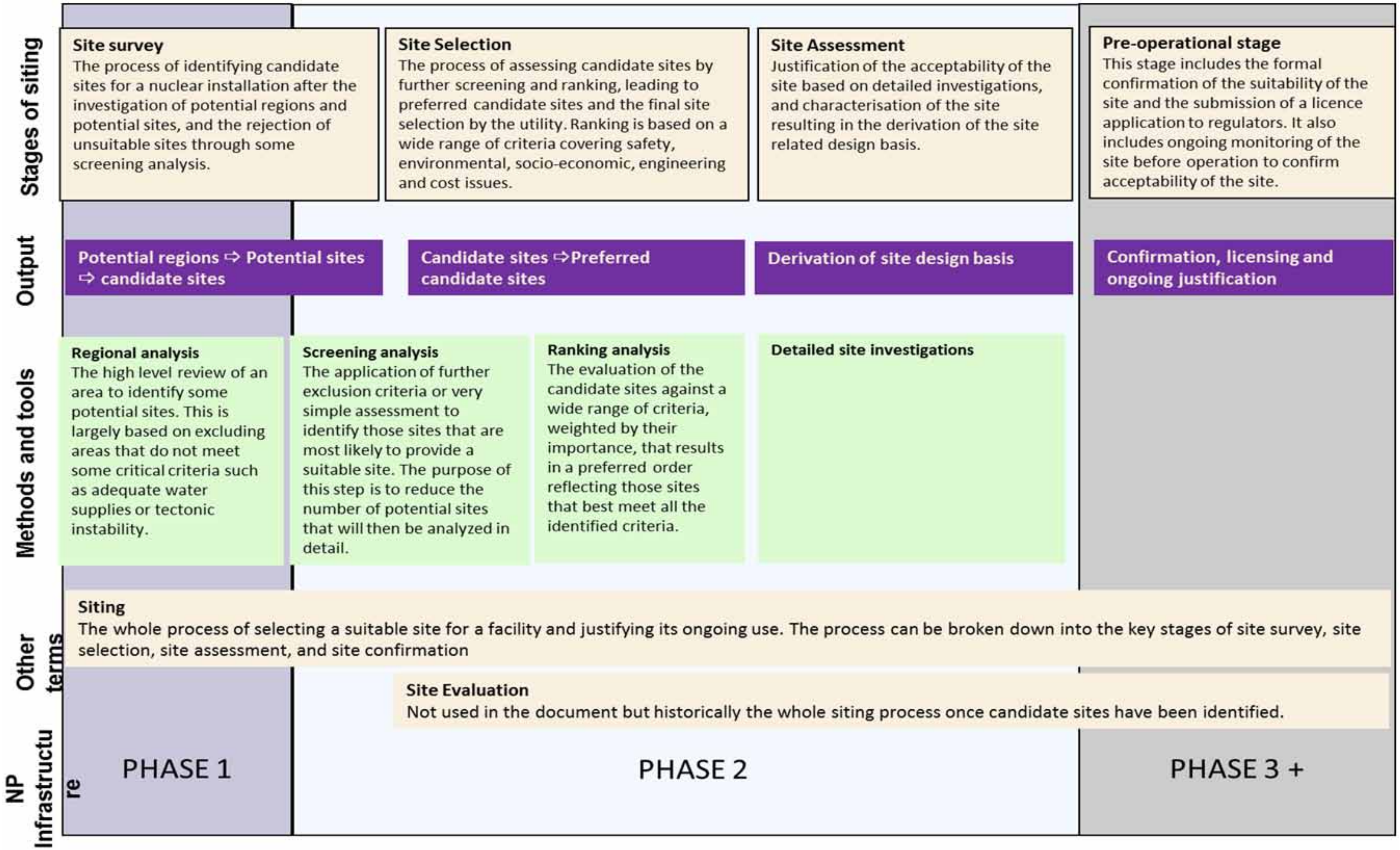
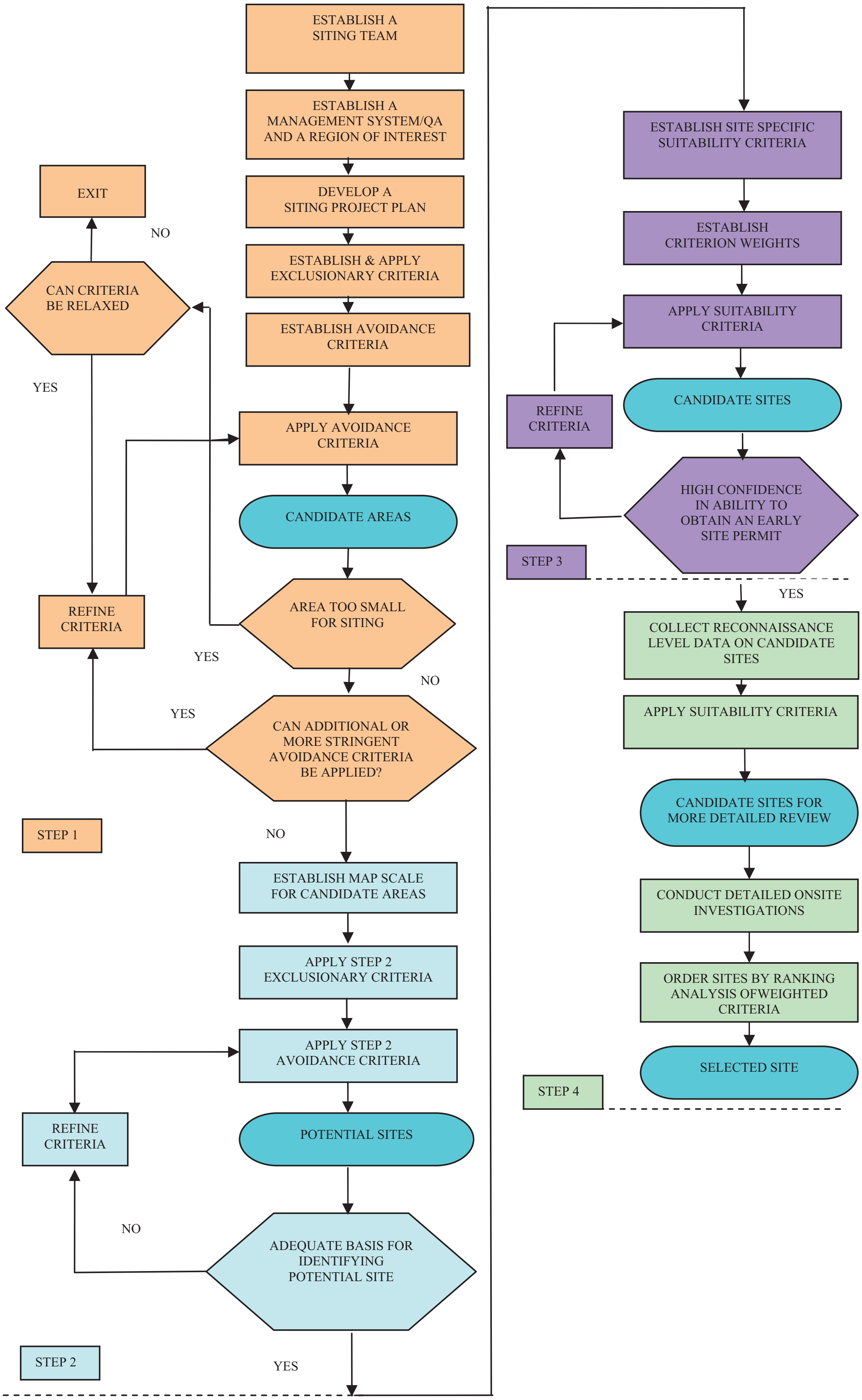


FIG. 8. Description of the siting process.

TABLE 2. SITING PROCEDURE



6. STAKEHOLDER INVOLVEMENT

The political, social and economic consequences arising from the use of nuclear energy have generated considerable public concern and debate. Mistakes and shortfalls in interaction with stakeholders can thwart excellent project management and can lead to an unfavourable public opinion which creates an image of the operating organization, the authorities and the project itself as something hostile.

When done well, stakeholder participation improves the quality and legitimacy of a decision and builds the capacity of all involved to engage in the process. It can enhance trust and understanding among parties. Stakeholder participation should be fully incorporated into the decision making processes, and it should be recognized by operating organizations, authorities and other stakeholders as a requisite of effective action, not merely a formal procedural requirement. Effective participation needs to be a dynamic two-way process. Simply dictating to the public or informing the public of decisions cannot be considered stakeholder participation. As has been said, "credibility is very hard to earn and very easy to lose".

It is for these reasons that the topic of stakeholder involvement is given a separate section in this publication. However, this section is not intended to be a comprehensive guide to effective stakeholder involvement. Much has been written on the topic and the IAEA has recently published a report entitled Stakeholder Involvement in the Lifecycle of Nuclear Facilities [13]. This section simply seeks to highlight some of the key issues. Those involved in the process directly should refer to the above mentioned publication.

6.1. GENERAL ISSUES

6.1.1. What is stakeholder involvement

The NEA/OECD Forum on stakeholder confidence defines stakeholder involvement as:

> "*An integral part of a stepwise process of decision making. At different phases, involvement may take the form of sharing information, consulting, dialoguing, or deliberating on decisions. It should be seen always as a meaningful part of formulating and implementing good policy. Stakeholder involvement techniques should not be viewed as convenient tools for 'public relations', image-building, or winning acceptance for a decision taken behind closed doors.*"

6.1.2. Who are the stakeholders

In simple terms, a stakeholder is usually defined as anyone who feels impacted by an activity, whether physically or emotionally. A useful sub-division, used in Ref. [13], is between 'statutory' and 'non-statutory' stakeholders. This distinguishes between those organizations and bodies that are required by law to be involved in any development and those that will be directly or indirectly impacted.

Statutory stakeholders therefore include the regulator, local or national planning authorities, various service related bodies (e.g. power, water and emergency planning) and national and local government entities involved in policy making and implementation.

'Non-statutory' stakeholders include those organizations and individuals who feel in whatever way impacted or affected by an activity (thus some stakeholders in this category may be self-selected). Local communities and non-governmental organizations (NGOs) fall into this group, and recognition of their importance cannot be overestimated. Their adequate inclusion or exclusion, for whatever reason, can contribute significantly to the success or failure of a nuclear facility project. The important point to remember is not to focus only on 'statutory' stakeholders but to conduct a broad stakeholder analysis to identify all the groups/individuals that may have an interest.

The actual stakeholders will be different from country to country and from life cycle stage to life cycle stage, but should be expected to include at least the following:

— Government leaders — local and national;
— News media;
— Academic/researchers;
— Medical and health professionals;
— Special and public interest groups, consumer groups, other non-governmental organizations;
— Employees and suppliers;
— The general public and, more specifically, the local community;
— Informal opinion makers.

6.1.3. The need for an integrated approach

6.1.3.1. Over the lifecycle of the facility

The lifecycle of the NPP may be considered by its owner as a range of discrete projects, for example:

— Strategic review of the role of nuclear power;
— Siting issues;
— Bidding and selection;
— Construction;
— Operation;
— Decommissioning;
— Etc.

It is important that those involved in such projects recognize that stakeholder involvement needs to be continuous and consistent through the various ‘projects’. The stakeholders do not see the same division as the managers of the projects. The process of stakeholder involvement and building trust within each project therefore needs acknowledgement that it is part of a bigger process.

6.1.3.2. Between organizations involved with stakeholders

During the process of deciding whether and where to construct a NPP, it is necessary for the organizations involved to coordinate their activities, while at the same time demonstrating a degree of independence so as to engender trust. The operating organization and the regulatory body should each develop their own information programmes and engage in public dialogue as they form and begin to exercise their responsibilities through their stakeholder involvement programmes.

The regulators’ role as an independent and competent body is important to establish and communicate. It is vital for the regulators to publicly demonstrate independence from political or industry influence in its decision making and deliberation. It is also becoming increasingly important for such bodies to develop clear avenues for stakeholder involvement in licensing processes. Many regulators incorporate opportunities for stakeholders to participate in their deliberative meetings. However, it should be recognized that this approach can be hampered by difficulties with access to documentation.

6.1.4. Stakeholder involvement plans

The first step in an effective stakeholder involvement process is the development of an appropriate strategy and a plan to implement the strategy. This requires a comprehensive approach to stakeholder identification and understanding of the issues or concerns affecting them. It then needs to define a clear decision making process with clearly defined responsibilities and roles. There needs to be clarity on the scope for decision making, and identification of the point(s) in the process when specific decisions are finalized and not subject to being revisited.

The timing of the various steps of consultation is important. Once the organization that is planning a NPP has sufficient information on the project, it should begin the stakeholder’s involvement and consultations with the public. If started to early, the consultations lack effect; if it’s taking place after the decision is made, it is futile. Timely public participation will help the project development as well as to acquire support of the stakeholders.

In no case should a particular stakeholder group's difficulty to comprehend issues be used as an excuse to withhold information.

It must be noted that a consensus on the decision (100% agreement) most of the times cannot be achieved. However, it is necessary for the stakeholders at least to understand the basis for the decision taken, even when they do not fully agree with it.

Further information related to stakeholder involvement plans is to be found in Refs [14, 15].

Some other key issues to consider are:

— ***Identification of participants*** — participants need to be representative of the identified stakeholder groups and speak with their authority;
— ***Establishing objectives*** — the early definition of objectives for the process will assist in ensuring that the activities of those participating are focused on results;
— ***Commitment to stakeholder involvement*** — if the stakeholders sense that the decision makers are not actively listening and acting on their input, the involvement programme will likely breakdown and may reduce trust;
— ***External constraints*** — these need to be clearly communicated and understood by stakeholders. Examples of these may include financial resources and regulatory obligations;
— ***Participation*** — different stakeholders will have differing levels of skills and resources. To ensure fairness and appropriate representation, it may be necessary to consider allocating additional resources (including information and training) to some groups or individuals in order that they can participate on an equal footing with other stakeholders;
— ***Flexibility*** — the participation process must remain flexible as the project proceeds in order to allow for input from stakeholders;
— ***Recognize future requirements*** — there will be an ongoing role of stakeholder involvement beyond the approval of a site. It is therefore vital that engagement with the younger generation forms an important part of the plan. The use of modern media such as social networking sites and the internet may be more suitable than traditional forms of print or broadcast communication.

More detailed guidance on developing a stakeholder involvement plan can be found in Ref. [13].

6.1.5. Stakeholder involvement in decision making

It is important to emphasize that stakeholder involvement is now a mandatory component of various international conventions and treaties that detail the role of governments and developers in strategic environmental assessment (SEA) and environmental impact assessment (EIA), not just for nuclear facilities. Development of a major national policy such as the introduction of a nuclear programme is subject to SEA requirements, and specific facilities and activities are subject to EIA requirements. While not all States are signatories to the relevant conventions and treaties such as Aarhus, Espoo, EURATOM or various EU Directives, these instruments are an example of how to incorporate responsibilities to the public, both nationally and in neighbouring countries. Taking those examples into consideration, the levels of stakeholder involvement should be determined by the States themselves.

It is also important to emphasize the difference between stakeholder involvement in decision making and general involvement through communication. Where actual decisions can be made by national or local stakeholders there is a real need for an effective process to allow suitable involvement. If communication of ongoing activities is simply an effort to inform the public but does not present real involvement in decision making, this should be made clear from the very start.

Increased public participation in decisions can promote a greater degree of understanding of the issues and can help to develop a more reasonable appreciation of the risks and benefits. In order to develop and enhance public confidence it is important to provide suitable opportunities for stakeholder involvement and develop new ways to obtain stakeholder input.

Certain high profile opinion leaders/formers may tend to be the most active and vociferous, but all concerned citizens should be provided with relevant information and have opportunities to participate in the dialogue. In fact, while high profile opinion leaders cannot be ignored, there is often considerable benefit to be gained working consistently with more local, often low profile, community groups and organizations, to gain their understanding and trust.

It is becoming more common for interested communities to be invited to volunteer their locations for potential development (provided they are suitable) as opposed to making top down imposed siting decisions. In many cases communities are being presented with potential benefits, both social and financial, and are able to decide whether or not to volunteer.

6.1.6. Identifying the benefits and addressing the issues of the NPP for the stakeholders

Open communication with stakeholders should address all of the benefits of nuclear power, nationally and locally, as well as risks, commitments and obligations. This honest approach is essential in order to build and maintain trust and confidence in a nuclear power programme.

It is important that all stakeholders recognize all of the benefits both local and national. The contribution to a national energy policy of greater independence from imported oil and gas is usually a primary point. There is also the benefit of reducing the environmental impact of fossil fuels. The benefits to the area can include jobs, tax revenues, economic output, labour income and incentives to the local community. Sub-section 4.6 identifies a number of potential socio-economic benefits.

The need for a safe and acceptable solution to the issue of waste management is likely to be an essential part of the debate, as is the need to demonstrate capability in decommissioning and waste management.

Other issues may include:

- Explaining plans for long term preservation of the environment;
- Compensation for damage or potential damage to local industry (fishery for example);
- Cost sharing for local infrastructure building;
- Land use after decommissioning;
- Water supply from (and in some cases to) the local community.

6.1.7. Stakeholders in neighboring countries

The Convention on Nuclear Safety (CNS) requests, among other things, that the State implementing a nuclear power programme consults with the neighbouring States and provides them with the necessary information, upon their request, to enable them to make their own impact assessment on their territories. Other treaties also require the involvement of neighbouring countries (see Sub-section 6.1.5).

Countries may set up, where appropriate, institutional arrangements or enlarge the mandate of existing institutional arrangements within the framework of bilateral and multilateral agreements. Harmonization of policies and measures for the protection of the environment in order to attain the greatest possible similarity in standards and methods related to the implementation of environmental impact assessment may also be required.

For example, the Espoo Convention on Environmental Impact Assessment in a Trans-boundary Context (EIA, adopted in 1991 and entered into force in 1997) is a document that is used as a framework for public participation rights of neighbouring countries in Europe. Such a convention helps set out the obligations of Parties in assessing the environmental impacts of certain activities at an early stage of planning, and can be used by States as a positive example.

6.1.8. Effective communication

Nuclear communicators must realize from the outset that they face scepticism and/or disbelief from some members of the general public and the media on almost any nuclear issue. The common fear that arises when anything ‘nuclear’ is involved, together with common misconceptions (such as that the steam coming out a NPP’s cooling tower is radioactive), will lead to unnecessary opposition and need to be tackled. Open and honest communication, with the communicators taking time to answer all questions arising, and taking the general public’s concerns seriously, can help to address issues that will otherwise hinder the siting process. The need for effective communication will increase as the demand for public participation in decision making on a wide range of environmental matters, including nuclear, continues to grow.

The majority of the general public will mainly rely on the information provided by the media. It is therefore important to plan for the education of the media and journalists, as well as the public. Public perception is volatile but not completely erratic. There are good practices in organizing public participation to ensure the best outcome is achieved. Hiring public information and communication experts to design and implement a communication campaign interwoven into the main project, is essential for successful implementation of a siting project. The expert assistance will steer the project communication process. It is also important to organize conversation sessions and open round table meetings with both pro- and anti-nuclear opinion formers such as engineers, scientists, politicians and journalists.

A comprehensive website and background documents on all aspects of the project, written in layman's language, will also be very useful in the communication process and stakeholder involvement.

A structured communication process includes a number of distinct activities:

- — Develop a set of clearly-defined objectives;
- — Identify the audience;
- — Identify the messages that will be presented to different stakeholders;
- — Identify the tools and approaches that will be used;
- — Design an evaluation component;
- — Assign ownership of plan elements;
- — Allocate sufficient resources to accomplish the actions;
- — Train those who will be involved to be effective communicators;
- — Implement and adjust the plan.

Further detail is provided in Ref. [13] and the following sections provide examples of activities that can be undertaken in the first three stages of the siting project. Obviously stakeholder involvement continues throughout the life of the NPP but this publication focuses on the three main siting stages.

6.2. STAKEHOLDER INVOLVEMENT ACTIVITIES

6.2.1. Stage 1 — Site survey (i.e. before specific sites have been selected)

In keeping with best industry practices, the proponent is expected to consult with stakeholders early in the siting process and before any substantive decisions is made. Initially this will be the responsibility of the NEPIO or, in its absence, the government department sponsoring the work or the proposed operating organization of the NPP.

This early stage of siting (involving identification of broad areas with potential sites) primarily involves the provision of information about the benefits of the project and the overall intent of the process. It will include items such as:

- — Developing a public participation plan;
- — Providing media releases and background reports, regularly and at key decision points;
- — Networking (e.g. small meetings and briefings) with Government and local officials, educational institutions, industry groups, media, and other opinion makers.

It is also important to seek to establish local and regional networks of expertise. These networks may be composed of technical experts in health, regional planning, land-use, and other fields. Such networks may contribute to the effectiveness of the siting process by identifying and further refining important criteria to be applied in subsequent steps. In addition, these networks may become future communication resources as the project reaches the site specific stage. Other activities may include:

- — Identifying other interested and affected parties that will need/want to be contacted immediately upon announcement of candidate sites;
- — Building communication channels with local and regional elected officials so that formal relationships are established before the announcement of candidate sites.

6.2.2. Stage 2 — Site selection

Initial activities may include:

- Organizing and supporting a public information office composed of project staff members, and advisory and technical review group members, who would be trained to make presentations to local civic and community groups;
- Conducting community interviews to identify interested and affected parties and to identify membership for a potential community advisory group (e.g. composed of elected and appointed officials, and leaders of community, environmental, and neighbourhood groups) that could provide useful input to the process and input that would be viewed as not necessarily influenced by the applicant's views;
- Arranging scientific visits of and/or visits to similar nuclear facilities for selected parties;
- Identifying and implementing communication mechanisms at the national level as well as for surrounding communities matching both with their interest(s) and the impact of candidate sites on their community.

Once some screening analysis has produced a list of candidate sites, more focussed activities could include:

- Developing a draft public participation plan for each candidate site;
- Establishing information centres within each community that hosts a candidate site;
- Conducting small meetings, workshops, and open houses at the information centres.

6.2.3. Stage 3 — Site assessment

At this site specific stage, the stakeholder involvement process should become even more interactive and activities and programs should be tailored to the characteristics and features of the site. Some enhancements to earlier plans may occur as the final preferred site or sites are identified. Networks should be refined, and more formalized mechanisms for soliciting stakeholder input should be devised and implemented. Activities should include the initiatives resulting from Stage 2 above, as well as additional efforts such as:

- Formally designating a site specific advisory or working group;
- Tailoring the stakeholder involvement plan to the site;
- Starting a site-specific newsletter, hotline, web site, and other communication devices.

GLOSSARY

candidate sites. A list of sites that appear suitable based on the Site Survey Stage.

NEPIO (Nuclear Energy Programme Implementing Organization). For countries introducing nuclear power, the NEPIO is the organization leading the effort for a nuclear power programme. It is responsible for: (i) for compiling all the information necessary for the government to make an informed decision on whether or not to proceed with the development of a nuclear programme and (ii) coordinating and overseeing the development of the necessary infrastructure (including the development of a competent regulatory body and operating organization) to bring the country to a point of issuing a bid for the first NPP project.

Nuclear energy/power programme. The nuclear power/energy programme is all the activities and projects aimed at developing nuclear power activities entailing sustained attention to many interrelated activities over a long duration and involving a commitment of at least 100 years throughout the installation planning, preparation, construction, operation, decommissioning and waste disposal management. A nuclear power/energy programme will require the establishment of a sustainable national infrastructure that provides governmental, legal, regulatory, managerial, technological, human and industrial support for the nuclear power programme throughout its life cycle.

Nuclear energy/power project. The nuclear power project is all activities that aim to build the physical nuclear power installation. This could be for the production of electricity, for seawater desalination or for any other peaceful purpose.

operating organization. An organization applying for authorization or authorized to operate an authorized facility and responsible for its safety. Any organization (and its contractors) which undertakes the siting, design, construction, commissioning and/or operation of a nuclear facility.

potential sites. Sites within the area of interest that have not been ruled out by the regional analysis.

preferred candidate sites. Those sites which are most suitable based on the ranking analysis and from which the State can choose the sites to implement its nuclear power programme.

ranking analysis. The evaluation of the candidate sites against a wide range of criteria, weighted by their importance which results in a preferred order reflecting those sites that best meet all the identified criteria.

regional analysis. The high level review of an area where there is an interest to build a nuclear power plant to identify some potential sites. This is largely based on excluding areas that do not meet some critical criteria such as adequate water supplies or tectonic stability.

regulatory body. An authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating nuclear, radiation, radioactive waste and transport safety.

review committee. A group of experts, decision makers and national authorities convened to advise, guide and decide on the selection of potential nuclear power sites. For countries introducing their first nuclear power installation, this Committee carries out the role of the Regulatory Authorities until they are set up.

safety analysis. Evaluation of the potential hazards associated with the conduct of an activity.

screening analysis. The purpose of this stage is to reduce the number of sites requiring to proceed in the ranking analysis stage to a few (less than 10) that can then be analyzed in detail. This involves either further exclusion criteria or very simple assessment to identify those sites that are most likely to provide a suitable site.

selected sites. The chosen site(s) for the nuclear power programme after the investigation of a large region, the rejection of unsuitable sites, and screening and comparison of the remaining sites.

site area. A geographical area that contains an authorized facility, authorized activity or source, and within which the management of the authorized facility or authorized activity may directly initiate emergency actions.

site assessment. Site assessment is aimed at providing information that forms the basis of a decision on whether or not the site is satisfactory. Various kinds of detailed investigations analysis may be used as tools in doing this. Hence an assessment may include a number of analyses, and result in the derivation of the site related design basis.

pre-operational stage. The final stage of the siting process, providing the site specific information needed for safety assessment. This stage should complete and refine the assessment of site characteristics. It also includes the finalization of the design of a nuclear installation and the preparation and submission of a licence application to the regulatory body. The site data obtained allow a final assessment of the simulation models used in the final design. Studies and investigations begun in the previous stages are continued after the start of construction and before the start of operation of the plant. It also includes the ongoing monitoring of the site before operation to confirm acceptability of the site.

site evaluation. Not used in the document but historically the whole siting process once candidate sites have been identified.

site selection. The process of assessing candidate sites by additional screening and ranking, leading to preferred candidate sites and the final site selection by the operating organization. Ranking is based on a wide range of criteria covering safety, environmental, socio-economic, engineering and cost issues.

site survey. The process of identifying candidate sites for a nuclear installation after the investigation of potential regions and potential sites, and the rejection of unsuitable sites through some screening analysis.

siting. The whole process of selecting a suitable site for a facility, definition of the related design bases, and justifying its ongoing use. The process can be broken down into the key stages of site survey, site selection, site assessment, and pre-operational.

siting seam. The group of people implementing a siting project.

The complete Glossary is included in Ref. [16].

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Appendix I

METHODOLOGIES FOR RANKING ANALYSIS

I.1. DIFFERENTIAL COSTS

One approach is to use the differential cost that would be required to make each site equal and seek to minimize this parameter. The assumption is made that a site with certain deficiencies, e.g. higher seismic input, will be equally safe as one with lesser seismic input as long as they are both designed to the required level of return frequency (the demand coming from the site characteristics). The negative aspect of the site with higher seismic input is quantified by the cost differential in the design and construction of the NPP for the higher seismic level.

It is not necessary to know the design details of any particular plant because eventually the differentials are relative. Data needed for the simplified calculations of external hazards and other design parameters related to the site should be collected.

The differential costs are calculated as follows:

- A standard design for the NPP is assumed (e.g. designed for 0.3g, Cessna type aircraft impact, Tornado load of F=3, etc.);
- A standard site is assumed for parameters such as grid loss, elevation with respect to cooling water source, etc.;
- The attributes of each site are evaluated with respect to these reference values;
- Some cost differentials are one time only and others continue through the lifetime of the plant.

Differential Cost Function = $\Sigma X_{Ai} + n \Sigma Y_{Ai}$ (where n is the number of years of plant operation).

An example of a calculation of a differential cost is shown in the table below:

TABLE 3. EXAMPLE OF A DIFFERENTIAL COST SITE

Parameter	Initial cost (total)	Continued Cost (per year)
Seismic (0.4g)	X_{A1}	Y_{A1}
Aircraft impact (Cessna)	—	—
Tornado (F3)	—	—
Soil improvement	X_{A4}	—
Coast elevation	—	—
Water temperature	—	Y_{A6}
Grid Loss	—	Y_{A7}
Infrastructure development	X_{A8}	—
Required Stack Height	—	—
Need for Cooling Towers	—	—
Cooling Water Pumping	—	Y_{A11}
Groundwater pumping	—	—
Site cut and fill	X_{A13}	—
Other		
Total	$\sum X_{Ai}$	$\sum Y_{Ai}$

I.2. SUITABILITY INDEX

This approach translates quantifiable site characteristics into a common suitability scale expressing preferences for one site over another. A typical suitability scale ranges 1–5, where the scale value of 1 is the lowest level of suitability (least preferable) and the scale value of 5 is the highest (most preferable). For example, with respect to emergency planning and distance to population centres, a site at a distance of 8 km could be assigned a suitability of 4 and a site at a distance of 2 km would be assigned a suitability of 1.

At this stage no attempt is made to prioritize criteria or to make the suitability scores equitable in any way.

Many ‘utility functions’ (distance in the case above) relate attributes to the suitability scale using a linear function. However, nonlinear functions are appropriate for other situations and would be defined based on the professional judgment of the discipline specialist.

In order to come to an overall decision, recognizing that it is unlikely that any one site will be the best against all criteria, it is necessary to assign a relative importance to each selection criterion; the relative importance should be reflected as a numerical weight value. In a simple example, if seismic impacts are considered to be twice as important as emergency planning effects, the former criterion might be assigned a weight twice as large as that for the latter. Assignment of weights is a sensitive issue in siting studies because the opinions and value judgments as to the relative importance of individual criteria vary with the perspectives of the individual stakeholder or group (e.g. operating organization, regulator, and public interest group).

There are a number of techniques for assigning importance weights to criteria. The ratio weighting technique places criteria in rank order and a value of 1 is assigned to the least important criterion. The evaluator then assigns numerical weights such that each of the remainder of the criteria receive a weight value depicting how much more important it is relative to the other ranked criteria. These relative weights are then normalized to 1.0.

After determination of the criterion weights, these normalized weights are then multiplied by the utility scores (1–5) for each of the criterion-weight pairs and these products summed to get an overall weighted score (composite suitability value) for each site. These composite suitability values can then be used to rank or compare sites in terms of their overall suitability. A possible variation on the use of a single consensus weighting for each criterion is the determination of separate site rankings using the consensus weightings of various stakeholder groups. These groups and their resulting site rankings can be brought together in an open, moderated group discussion to find common ground for an agreed-upon identification of the selected sites.

Sensitivity studies using different criterion weights can be conducted to assess their effect on the selection of a preferred site and thereby lend additional credibility to the decision process. There are a variety of methods for developing criterion weight values (e.g., nominal group technique, modified Delphi, and Kepner-Tregoe) but discussion of these techniques is beyond the scope of this report.

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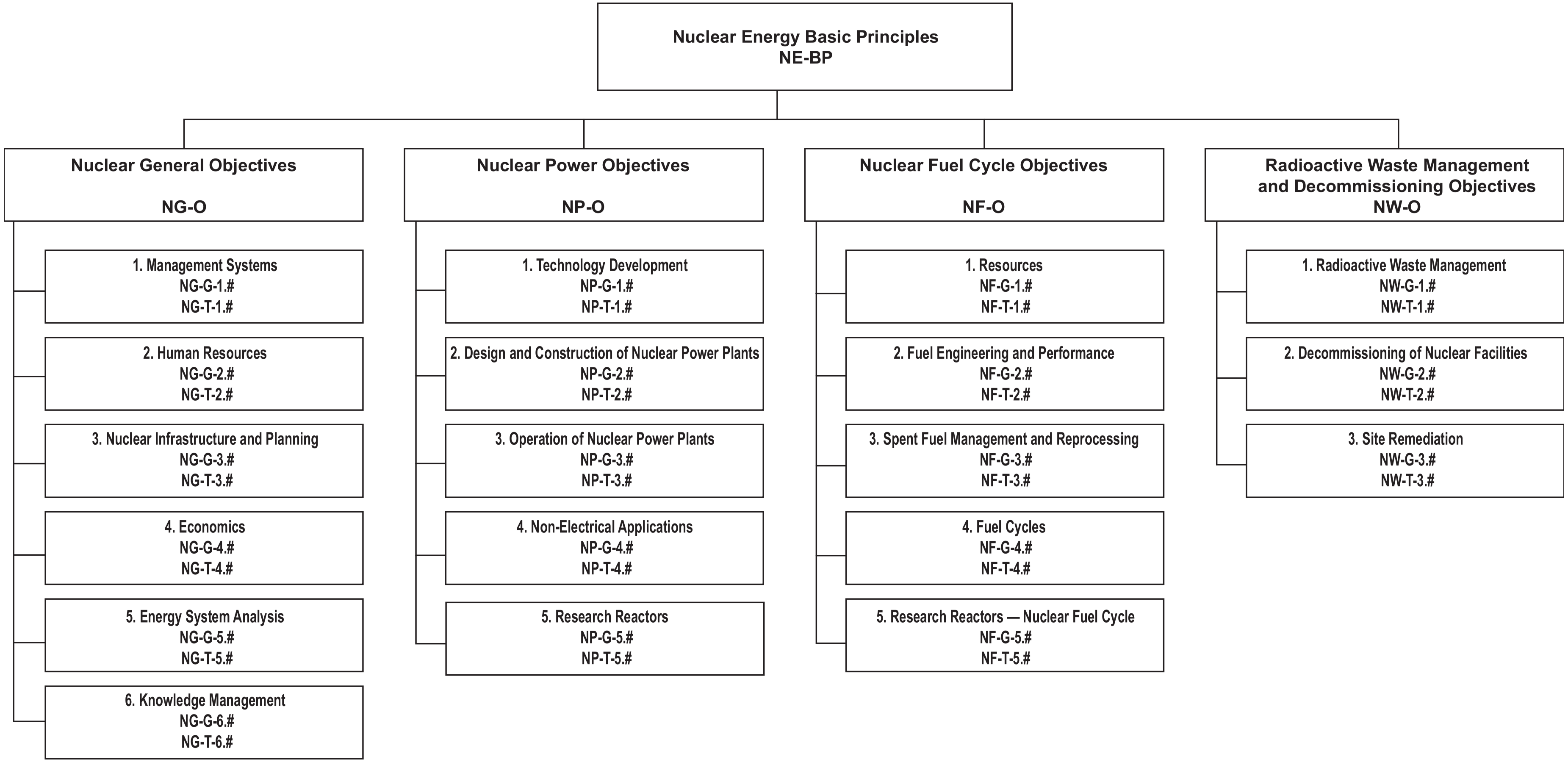

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