IAEA
International Atomic Energy Agency

IAEA NUCLEAR ENERGY SERIES No. NG-G-3.1 (Rev. 2)

Milestones in the Development of a National Infrastructure for Nuclear Power

GUIDES

IAEA NUCLEAR ENERGY SERIES PUBLICATIONS

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MILESTONES IN THE DEVELOPMENT OF A NATIONAL INFRASTRUCTURE FOR NUCLEAR POWER

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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".

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INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2024

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email: sales.publications@iaea.org
www.iaea.org/publications

Printed by the IAEA in Austria
June 2024
STI/PUB/2073
https://doi.org/10.61092/iaea.zjau-e8cs

IAEA Library Cataloguing in Publication Data

Names: International Atomic Energy Agency.
Title: Milestones in the development of a national infrastructure for nuclear power / International Atomic Energy Agency.
Description: Vienna : International Atomic Energy Agency, 2024. | Series: IAEA nuclear energy series, ISSN 1995–7807 ; no. NG-G-3.1 (Rev. 2) | Includes bibliographical references.
Identifiers: IAEAL 23-01631 | ISBN ISBN 978-92-0-150223-0 (paperback : alk. paper) | ISBN 978-92-0-150423-4 (pdf) | ISBN 978-92-0-150323-7 (epub)
Subjects: LCSH: Radiation — Safety measures. | Nuclear power plants — Safety measures. | Nuclear power plants — Management.
Classification: UDC 621.039 | STI/PUB/2073

FOREWORD

The IAEA's statutory role is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world". Among other functions, the IAEA is authorized to "foster the exchange of scientific and technical information on peaceful uses of atomic energy". One way this is achieved is through a range of technical publications including the IAEA Nuclear Energy Series.

The IAEA Nuclear Energy Series comprises publications designed to further the use of nuclear technologies in support of sustainable development, to advance nuclear science and technology, catalyse innovation and build capacity to support the existing and expanded use of nuclear power and nuclear science applications. The publications include information covering all policy, technological and management aspects of the definition and implementation of activities involving the peaceful use of nuclear technology. While the guidance provided in IAEA Nuclear Energy Series publications does not constitute Member States' consensus, it has undergone internal peer review and been made available to Member States for comment prior to publication.

The IAEA safety standards establish fundamental principles, requirements and recommendations to ensure nuclear safety and serve as a global reference for protecting people and the environment from harmful effects of ionizing radiation.

When IAEA Nuclear Energy Series publications address safety, it is ensured that the IAEA safety standards are referred to as the current boundary conditions for the application of nuclear technology.

Energy is essential for development. Nearly every aspect of development — from reducing poverty and raising living standards to improving health care and industrial and agricultural productivity — requires access to modern energy sources. Current forecasts suggest that global electricity use will increase substantially by 2050, with most of the growth in developing countries. Many IAEA Member States that do not have access to nuclear power have expressed an interest in introducing it in order to meet their energy needs without increasing reliance on fossil fuels.

The wide range of infrastructure issues that need to be considered when introducing nuclear power were described in the 2007 publication IAEA Nuclear Energy Series No. NG-G-3.1, Milestones in the Development of a National Infrastructure for Nuclear Power, which laid out a three phase sequential process for developing a nuclear power programme. It provided a detailed description of all infrastructure issues to be addressed and the expected level of achievement for each issue by the end of each phase. The publication was well received and widely used, and its framework and terminology have been broadly adopted.

In 2015, the IAEA published a revised version (Rev. 1) to reflect several developments since the original publication. The revision incorporated practical lessons from missions based on the Milestones approach that were carried out in countries introducing or expanding nuclear power as part of the Integrated Nuclear Infrastructure Review (INIR) service. It also considered lessons learned from the 2011 Fukushima Daiichi accident and from the implementation of the IAEA Action Plan on Nuclear Safety, and expanded the publication's original focus on a competitive bidding process to include approaches involving, for example, strategic partners and sole suppliers, and direct negotiations through intergovernmental agreements.

Since the publication of the first revision, another 19 INIR missions have been conducted, including the first two Phase 3 INIR missions, and two embarking countries that developed their national programmes using the Milestones approach have started operating their first units. Other embarking countries are currently in the stage of negotiating contracts with technology providers or are in an advanced stage of construction and infrastructure development. Several new IAEA publications on specific infrastructure issues have also been published in the interim. These changes are covered in the present revision (Rev. 2).

This revision also considers the recent developments on small and medium sized or modular reactors (SMRs). SMRs are nuclear installations and, in that regard, the 19 infrastructure issues of the Milestones approach generally apply. However, this publication addresses, as appropriate, aspects of the infrastructure that can be implemented or considered differently in the context of SMR deployment. The publication includes an annex outlining the specific infrastructure considerations for SMRs, with a focus on a subset of SMRs that are in an advanced stage of development, such as integrated pressurized water reactors and high temperature gas cooled reactors.

This publication can be used by embarking countries and by countries seeking to expand an existing nuclear power programme to help to assess their preparedness. Suppliers, nuclear energy agencies and utilities may also find assessments based upon this publication useful. Such assessments could build confidence that the relevant entities in these countries are able to regulate, construct and operate nuclear power plants safely and securely.

The guidance included here is provided within the context of the IAEA's other guidance and materials relevant to nuclear power development. These include IAEA Safety Standards Series No. SSG-16 (Rev. 1), Establishing the Safety Infrastructure for a Nuclear Power Programme; IAEA Nuclear Security Series No. 19, Establishing the Nuclear Security Infrastructure for a Nuclear Power Programme; and IAEA Services Series No. 21, Guidance for States Implementing Comprehensive Safeguards Agreements and Additional Protocols.

The IAEA officers responsible for this revision were J. Bastos, M. Ceyhan and M. Kovachev of the Division of Nuclear Power.

EDITORIAL NOTE

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CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

A nuclear power programme is a major undertaking that requires careful planning, preparation and investment in studies, institutions and human resources. While nuclear power is not alone in this respect, it has specific characteristics because of the safety, security and safeguards requirements associated with using nuclear material.

A decision to start a nuclear power programme should be based on a commitment to use nuclear power safely, securely and peacefully and should recognize the need for adequate financial and human resources to implement the programme successfully. The benefits of a nuclear programme for the country should also be clearly defined. As well as the provision of energy at an acceptable price, these benefits can also include energy security, socioeconomic benefits and mitigation of climate change. The necessary commitment requires establishing a sustainable national infrastructure that provides governmental, legal, regulatory, managerial, technological, human resource, industrial and stakeholder support for the nuclear power programme throughout its life cycle.

The required infrastructure includes not only 'hard' infrastructure (e.g. grid and transport infrastructure), but also the human and financial resources and the legal and regulatory framework within which the programme will be carried out. Essentially, the same infrastructure elements are needed whether the programme considers a large nuclear power plant (NPP) or a small and medium sized or modular reactor (SMR), and whether it is planned for producing electricity, for seawater desalination or for any other peaceful purpose, though there may be aspects of the infrastructure that can be implemented or considered differently. It is the responsibility of the country introducing nuclear power to establish the necessary infrastructure. Those supplying equipment to a new nuclear power programme will expect progress on a schedule that will ensure that their products are used safely, securely and sustainably.

This publication is intended to provide guidance for the benefit of those starting or expanding such programmes, based on the relevant international legal instruments, IAEA safety standards and guidance provided in other IAEA publications such as those in the IAEA Nuclear Energy Series and IAEA Nuclear Security Series, as well as the experience and good practices of countries that already have NPPs in operation. Experience has shown that early attention to the 19 infrastructure issues presented here will facilitate a successful nuclear power programme. Insufficient attention to any of them may lead to costly delays or even project failure. This publication assumes that a country contemplating

the introduction of nuclear power has a stable political, economic and social environment.

The guidance offered in this publication recognizes that many embarking countries are looking for proven technologies that have been licensed in the country of origin of the technology or in another, more experienced country. This is particularly important for the regulatory body of an embarking country as it will benefit from the support of a more experienced regulator in the licensing process.

Timescales for nuclear power are long. Each NPP involves a commitment in the order of 100 years, through construction, operation, decommissioning and waste disposal. Experience suggests that the time from the initial consideration of the nuclear power option by a country to the operation of its first NPP is about 10–15 years. This could vary depending on the resources devoted to the programme and the type of technology chosen, whether a large NPP or an SMR.

The use of nuclear material requires constant attention to *nuclear safety*, *nuclear security* and *safeguards*. This is the country's responsibility, not only to its own citizens but also to the international community. It is embodied in both international and national legal instruments.

Regarding *nuclear safety*, the fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation. A comprehensive safety framework needs to be developed that permeates many of the infrastructure issues described in this publication. The IAEA safety standards provide a system of Safety Fundamentals, Safety Requirements and Safety Guides reflecting an international consensus on measures to ensure a high level of safety. The Safety Standards Series publications also include a roadmap for safety infrastructure development for use by countries contemplating the introduction of nuclear power.

Regarding *nuclear security*, the fundamental security objective is to protect persons, property, society and the environment from the harmful effects of a nuclear security event. Nuclear security focuses on the prevention of, detection of and response to criminal or intentional unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities or associated activities. As with safety, a comprehensive national nuclear security regime needs to be developed to achieve nuclear security goals.

Regarding *safeguards*, the objective is to provide assurance that States are fulfilling their commitments concerning the peaceful use of nuclear energy and deters States, through the risk of early detection, from acquiring or using nuclear material, facilities and/or other items subject to safeguards.

Ensuring safety, security and safeguards and achieving sustainable operation goals require the development of a culture within each organization and the implementation of systems and practices to ensure that all staff are aware of their responsibilities and the importance of their actions.

1.2. OBJECTIVE

This publication defines milestones in the development of the infrastructure necessary for introducing nuclear power and provides guidance on the activities that need to be carried out before each milestone. A country can use it to ensure the following:

— It recognizes the commitments and obligations associated with the introduction of nuclear power.
— It has adequately prepared the entire national infrastructure for building an NPP.
— It has developed all the capabilities needed to regulate, oversee construction of and operate an NPP safely, securely and sustainably and to manage the resulting spent fuel and radioactive waste.

Guidance and recommendations provided here in relation to identified good practices represent expert opinion but are not made on the basis of a consensus of all Member States.

1.3. SCOPE

This publication covers both the 'hard' infrastructure (e.g. electrical grid, sites) and 'soft' infrastructure (e.g. nuclear law, regulations, training) needed for a nuclear power programme. It covers infrastructure needs from the time a country first considers the nuclear power option, through decision making, planning, procurement, construction and preparations for operation. Subsequent steps — operation, decommissioning, spent fuel and radioactive waste management — are addressed only to the degree necessary for planning purposes prior to operation. They are included because all stages, including operation and decommissioning, as well as spent fuel and radioactive waste management, should be considered when the decision is made to proceed with nuclear power and because planning for these stages should be in progress by the time specifications for the plant are set. By the time the country is ready to operate an NPP, it should also be ready to manage the longer term commitments associated with operation, spent fuel and radioactive waste management, and decommissioning.

1.4. USERS

This publication is principally for decision makers, advisers and senior managers in government entities including ministries, the nuclear energy programme implementing organization (NEPIO) and legislative body, owner/operator organizations and regulatory bodies in a country interested in introducing nuclear power.

Third party organizations, such as suppliers and nuclear energy agencies, may use this publication to assess a country's progress in developing the infrastructure necessary for nuclear power and to provide timely and meaningful assistance. This publication could be used to increase confidence that the country has the infrastructure necessary for nuclear power or to identify areas for potential assistance.

Countries interested in expanding existing nuclear power programmes may also find the publication helpful, particularly if it has been a long time since they last built an NPP.

1.5. STRUCTURE

This publication has two sections in addition to this introduction. Section 2 presents the three major infrastructure milestones in the development of a nuclear power programme. Section 3 presents 19 infrastructure issues and, for each issue, the main activities to be carried out in order to reach each milestone.

An annex, dedicated to specific infrastructure considerations for SMRs that are in advanced stages of development, has been added to this revision.

1.6. USING THIS PUBLICATION

This publication is intended to help a country to plan the steps necessary to develop a national infrastructure for nuclear power and to assess its progress towards that goal. It is not a comprehensive guide on how to create the entire infrastructure needed for a nuclear power programme, but rather presents the elements of infrastructure that should exist at significant points in the development process. More detailed information and guidance on the activities associated with each of the 19 infrastructure issues is available in the IAEA

publications listed in the regularly updated Nuclear Infrastructure Bibliography[1] and the IAEA Nuclear Infrastructure Competency Framework[2].

In addition, the IAEA provides peer reviews and advisory services to support countries in the development of nuclear power infrastructure. One of these is the Integrated Nuclear Infrastructure Review (INIR) service, which provides a holistic view considering all 19 infrastructure issues[3]. The IAEA also implements a legislative assistance programme to address international and national nuclear law.

2. THE PROGRAMME TO DEVELOP INFRASTRUCTURE

2.1. INFRASTRUCTURE MILESTONES

The activities needed to prepare the infrastructure for nuclear power can be split into three phases, with the duration of each phase dependent on the degree of commitment and the resources applied in the country. The term 'infrastructure milestone' is used to identify the point at which all the activities required in that phase of development have been successfully completed. Each infrastructure milestone therefore corresponds to the completion of a set of activities with no implications about the speed with which it is reached. The operation and decommissioning phases are not covered in this publication, but are covered more extensively in other IAEA publications.

The three phases in developing the infrastructure necessary to support a nuclear power programme are as follows:

— Phase 1: Considerations before a decision to launch a nuclear power programme is taken;
— Phase 2: Preparatory work for the contracting and construction of an NPP after a decision has been taken;
— Phase 3: Activities to implement the first NPP.

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[1] Available at https://www.iaea.org/topics/infrastructure-development/bibilography#1

[2] Available at https://nucleus.iaea.org/competency-framework

[3] See INTERNATIONAL ATOMIC ENERGY AGENCY, Guidelines for Preparing and Conducting an Integrated Nuclear Infrastructure Review (INIR), IAEA Services Series No. 34, IAEA, Vienna (2017).

The completion of each phase is marked by a specific milestone where the progress of the development effort can be assessed and a decision can be made to move on to the next phase. These milestones are as follows:

— Milestone 1: Ready to make a knowledgeable commitment to a nuclear power programme;
— Milestone 2: Ready to invite bids/negotiate a contract for the first NPP;
— Milestone 3: Ready to operate the first NPP.

Figure 1 is a schematic representation of the phases and milestones.

It is important to understand the distinction between a programme and a project. The three phases and three milestones refer to developing the national infrastructure to support a nuclear power *programme*. The programme includes one or more NPPs and the supporting infrastructure; it could also include possible related projects such as uranium exploration and fuel fabrication. As the programme develops, many specific activities are undertaken to implement the first NPP *project*. Projects are temporary undertakings to develop and construct NPPs. The infrastructure provides the processes and capabilities to enable the project activities and the subsequent operation of the NPP to be implemented safely, securely and sustainably.

The time frame (as Fig. 1 shows) of at least 10 to 15 years from the beginning of Phase 1 to Milestone 3, reflects the experience of Member States

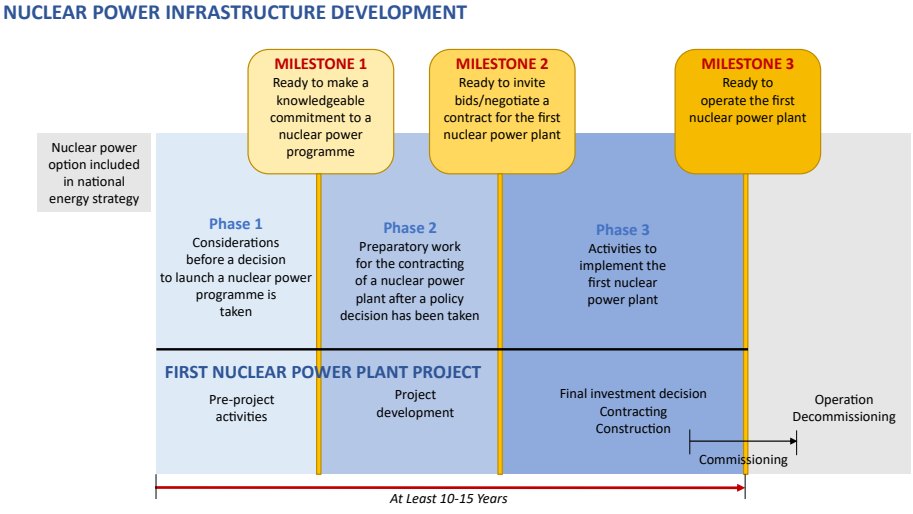

FIG. 1. Development of the infrastructure for a national nuclear power programme.

based on large NPP projects. It is expected that this time will be shorter if an embarking or expanding country decides to build an SMR.

In the development of the nuclear power infrastructure, three key organizations are involved: the government, the owner/operator of the NPP and the regulatory body. Each has a specific role to play, with responsibilities evolving as the programme advances.

The owner/operator may be State owned or private, be part of a domestic utility or be another commercial entity. The owner organization may also be different from the operator entity. This is discussed further in Section 3.3, on management. This publication distinguishes between the owner and operator when it is important to do so and uses the combined term 'owner/operator' when the distinction is less important.

The regulatory body should expand and develop key competences that are necessary in the regulatory decision making process. It must have sufficient authority, staffing and financial resources, and operate free from any undue influences, such as pressures associated with changing political circumstances or economic conditions, or pressures from government departments or other organizations. Recent experience has shown that most embarking countries are adopting a single regulator that is responsible for safety, security and safeguards. However, it is possible to have more than one regulatory body addressing these areas. This publication refers to 'regulatory body' in the singular and this term should be understood to include separate authorities where applicable.

In this publication, it is assumed that the government will create a mechanism (which may involve high level and working level committees) to coordinate the work of these and other organizations involved in infrastructure development. This mechanism is called the NEPIO. It should be noted that this designation is used here for illustrative purposes only. The country may organize the activity in the manner most appropriate for its own customs and needs. This NEPIO mechanism is responsible for all the Phase 1 activities and for developing a report to enable the national decision makers to make a knowledgeable decision on whether to launch the nuclear power programme. In Phases 2 and 3, it is responsible for coordinating the development of the nuclear power infrastructure.

Table 1 shows the 19 infrastructure issues that need to be considered for each milestone. The order does not indicate relative importance. Each issue is important and requires careful consideration. Different organizations will need to consider which issues relate most to them and to plan their work and resources accordingly. The three key organizations — the government, the owner/operator and the regulatory body — need to ensure awareness of all issues.

TABLE 1. INFRASTRUCTURE ISSUES

The 19 infrastructure issues	
1. National position	11. Stakeholder engagement
2. Nuclear safety	12. Site and supporting facilities
3. Management	13. Environmental protection
4. Funding and financing	14. Emergency preparedness and response
5. Legal framework	15. Nuclear security
6. Safeguards	16. Nuclear fuel cycle
7. Regulatory framework	17. Radioactive waste management
8. Radiation protection	18. Industrial involvement
9. Electrical grid	19. Procurement
10. Human resource development	

2.2. MILESTONE 1: READY TO MAKE A KNOWLEDGEABLE COMMITMENT TO A NUCLEAR POWER PROGRAMME

At the beginning of Phase 1, it is assumed that a country has determined that it needs additional energy while limiting CO_2 emissions to address climate change, and it has considered nuclear power as a possible option to meet some of these needs. During Phase 1, the country will analyse all issues that would be involved in introducing nuclear power, so that at the end of Phase 1, it can make a knowledgeable decision on whether or not to introduce nuclear power.

In Phase 1, it is essential that the country acquire a comprehensive understanding of the obligations and commitments involved and requirements to fulfil them, and plan and estimate the cost for their implementation before taking any decision.

A country considering nuclear power could already have infrastructure covering any current activities with radiation sources or research reactors. Building on the existing infrastructure and associated experience should greatly assist the country in establishing the necessary infrastructure for a nuclear power programme.

In Phase 1, the NEPIO should ensure overall coordination, ensure the engagement of all important parties, compile the information and perform the studies necessary for a knowledgeable decision on whether to proceed with nuclear power. At the end of Phase 1, the NEPIO should develop a comprehensive report that, should it recommend a positive national decision, defines and justifies a national strategy for nuclear power. Any prefeasibility study done during Phase 1 can be a significant input to the comprehensive report, although it is important that the report fully address all 19 infrastructure issues described in Section 3.

2.3. MILESTONE 2: READY TO INVITE BIDS/NEGOTIATE A CONTRACT FOR THE FIRST NUCLEAR POWER PLANT

Following the decision to proceed with the development of a nuclear power programme, substantive work for achieving the necessary level of technical and institutional competence should be undertaken. This phase requires continuing support from the government through the relevant ministries and agencies. Several infrastructure elements should be in place at Milestone 2, including those related to the legal and regulatory framework and the establishment of key organizations. It is also important that the work of all organizations continue to be well coordinated and driven through the NEPIO. The key NEPIO functions during Phase 2 include the following:

— Maintaining momentum and providing a continuing forum for communication and cooperation among the organizations described throughout Section 3 (e.g. the owner/operator, the grid operator, the regulatory body, relevant government agencies, legislators and other decision makers);
— Ensuring that the roles of the key organizations (i.e. the government, regulatory body and owner/operator) are well defined and understood by all stakeholders;
— Ensuring that the key organizations develop in line with the programme roadmap;
— Ensuring that the rationale for the national decision to introduce nuclear power is well understood by all stakeholders;
— Ensuring that the contracting approach and technical specifications remain consistent with the country's nuclear power development strategy.

During Phase 2, the country should develop the necessary infrastructure, covering all 19 infrastructure issues, to the point of complete readiness to invite bids / negotiate a commercial contract between the owner/operator and potential technology suppliers. An effectively independent regulatory body should be developed to a level at which it can fulfil all its authorization and inspection duties. At this early stage of the programme, the regulatory body may require substantial support from consultants or technical support organizations (TSOs) (including from an experienced regulator that has licensed similar facilities) to perform its tasks.

The owner/operator has a key role in ensuring that, by the end of Phase 2, it has developed the competence to manage a nuclear power project, meet regulatory requirements and be a knowledgeable customer in Phase 3. The owner/operator should also have, by the end of Phase 2, plans to develop or acquire during

Phase 3 the capability to safely operate the plant. These plans may well involve partnership with organizations experienced in the operation of NPPs.

2.4. MILESTONE 3: READY TO OPERATE THE FIRST NUCLEAR POWER PLANT

For countries using competitive bidding, Phase 3 starts with the bidding and subsequent negotiation of the contract for the design, construction and commissioning of the NPP. For other countries, Phase 3 starts directly with the negotiation of the contract. Much of the work on infrastructure development will be well advanced by the beginning of Phase 3, but the greatest capital expenditure for the NPP will occur during Phase 3. Depending on the specific agreements between the owner/operator and the contractor(s), the contract may involve different phases of work (e.g. detailed design, construction, and/or commissioning) with different price agreements (e.g. fixed price, cost plus). After agreement on the contract, investors may wait for final project cost and schedule agreements and other financial arrangements before making the final investment decision. Whatever the detailed contract arrangements may be, the final investment decision is a pivotal step.

The initial work will be to develop the site specific design, produce the preliminary safety analysis report (PSAR) and achieve all the required licensing and planning approvals. At this stage, the project costs and schedule can be finalized. Subsequent work will then include management and supervision of the construction contract. For the regulatory body, assessment of the PSAR and granting of the construction licence will be a major task, followed by all regulatory oversight and approvals throughout the phase.

The commonly observed contracting approach in embarking countries is the turnkey or EPC (engineering, procurement and construction) contract. In this type of contract, site specific design modifications are under responsibility of the contractor, which is also responsible for developing most of the chapters of the PSAR, the procurement of components and services and the construction of the NPP. The owner/operator remains responsible for applying for the required licences and defending the safety case in front of the regulatory body. The owner/operator is equally responsible for implementing an oversight programme to ensure that the project is implemented in line with the contract requirements.

Experienced expanding countries may adopt the split package approach, in which the procurement of the NPP is divided into several elements (e.g. nuclear island, turbine island) and the owner/operator is responsible for the integration of these elements within the overall project.

Whatever the contractual arrangement may be, the owner/operator has a key role during commissioning. The purpose of commissioning is to ensure that structures, systems and components function as per their requirements and that commissioning activities are typically jointly implemented by the commissioning team of the contractor and the owner/operator. Commissioning starts during construction with system testing and handover, followed by cold functional and hot functional tests, and continues with fuel loading, first criticality and power ascension tests.

At the end of Phase 3, the owner/operator must be fully capable of, and licensed for, operating the NPP. If the owner/operator has been newly created, or is new to nuclear power, this will require significant development and training for all staff and a demonstration that the owner/operator can manage the NPP throughout its lifetime.

The regulatory body will have been in operation for some time, having developed regulations and guides, licensed construction of the plant, carried out inspections during construction, approved a commissioning programme and provided an operating licence. It should now be clearly seen as a competent, effectively independent regulatory body able to provide continuing oversight of all facilities and activities and enforce continuing compliance with all regulatory requirements.

The competence of both the owner/operator and the regulatory body may be ensured through expertise and support from experienced foreign organizations, including from the NPP supplier country. Consideration should be given to the need to ensure competence throughout the lifetime of the NPP.

The experience of advanced embarking countries has shown that two subphases can be observed during Phase 3: an initial subphase where the focus of the organizations is on contracting, licensing and construction oversight and a second, overlapping subphase focused on the preparation for the operational phase. This change of focus has implications on the priorities for the owner/operator and regulatory body and on the structure of the organizations, training programmes, management systems, etc.

While achieving Milestone 3 is a major accomplishment, it should be remembered that it is only the beginning of a lasting commitment to the safe, secure, peaceful and sustainable application of nuclear power.

3. DESCRIPTION OF INFRASTRUCTURE ISSUES

Each of the 19 infrastructure issues presented in this section requires specific actions during each of the three phases. Completion of the actions for a phase represents attainment of the associated milestone. Those actions are described here at a relatively high level. More details are available in the IAEA publications listed in the Nuclear Infrastructure Bibliography[4].

Although each infrastructure issue is considered separately, it should be recognized that there are interconnections among the issues. For example, radioactive waste management is one of the issues (Issue 17) but funding for radioactive waste management is also addressed (Issue 4). Similarly, regulatory framework (Issue 7) addresses the overall establishment of the framework, but specific areas are discussed under the issues related to nuclear safety (Issue 2), nuclear security (Issue 15) and safeguards (Issue 6). Also, the order in which the 19 infrastructure issues are presented does not imply relative importance. All are important and require appropriate attention.

3.1. NATIONAL POSITION

Prior to any formal studies of the implications of introducing nuclear power, the government and any project proponent will have carried out initial energy planning, considered aspects of climate change mitigation and identified any other potential uses of nuclear energy, such as water desalination, district heating and cooling, and industrial heat, and the wider potential benefits of nuclear power.

The establishment of the national position provides the foundation for the future development and implementation of the nuclear power programme. The development of the national position is the result of a technical and governmental process and may take various forms depending on a State's specific governmental structure. The national position is generally developed in Phase 1 and then maintained and updated as required in Phases 2 and 3.

The national position establishes the governmental strategy and commitment to develop, implement and maintain a safe, secure and sustainable nuclear power programme and to meet the international obligations of the State as well as international norms and standards. A national position explains the

[4] Available at https://www.iaea.org/topics/infrastructure-development/bibliography#1

role of nuclear power in supporting the economic, social, environmental and development objectives of the State. It contains three main elements:

— The national energy policy and the role of nuclear power in the energy mix;
— The need for involvement of all stakeholders, at local, regional, national and international levels;
— An informed statement of the infrastructure and institutions that are necessary to support a nuclear power programme, including relevant international legal treaties and conventions.

While nuclear energy is most often used to generate electricity, if there is an intention to develop nuclear powered desalination or process heat production, this should also be addressed in the statement of the national position.

Strong government support at every stage is vital to the success of a nuclear power programme. The intention to develop such a programme should be announced at the most senior level of government. Government leadership and funding is required for initial programme development, and continued government support will be required throughout the lifetime of the nuclear power programme. The government will also have to consider underwriting certain financial risks associated with the programme through, for example, loan guarantees or a power purchase agreement. Careful consideration should be given to the means of maintaining the long term political, economic and social stability that will be required for a successful programme.

3.1.1. National position: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

At this very early stage it is vitally important that the government (and the project proponent if not part of the government) recognize that the introduction of nuclear power requires long term commitments, both nationally and internationally. A time frame in the order of 100 years should be considered for an NPP, with waste disposal obligations extending significantly longer.

A full understanding of the commitments can best be achieved by forming a NEPIO (see Section 2.1). Its principal purpose in Phase 1 is to undertake the wide range of studies needed to develop the three elements of a national position defined above. This will provide the government with all the information necessary for a knowledgeable decision on whether to proceed at this time with the development of a nuclear power programme.

The NEPIO should have clear terms of reference to that effect. Its role should be recognized by all relevant government ministries and organizations. It should report to a senior minister or directly to the head of the government and be

given the resources and staff necessary to perform its functions and tasks. It may make considerable use of consulting expertise, but it is critical that leadership remain with the NEPIO. The NEPIO should ensure communication among and engagement and cooperation of all important parties, including the country's major utilities, the regulatory body for security and radiation safety, other relevant government agencies, legislative representatives and other decision makers. Key staff from a number of these organizations should be directly involved in the NEPIO work programme. The NEPIO should establish a policy and guidance to inform interested parties of the benefits, costs and risks of nuclear power in order to facilitate their involvement in the decision making.

At the end of Phase 1, the NEPIO should produce a comprehensive report that, should it recommend a positive national decision, defines and justifies a national strategy for nuclear power. Any prefeasibility study done during Phase 1 can be a significant input to the comprehensive report, although it is important that the report fully address all 19 infrastructure issues. It should include the following:

— An analysis of energy demand and energy alternatives;
— An evaluation of the impacts of nuclear power on the national economy (e.g. gross domestic product, employment);
— A preliminary technology assessment to identify technologies that are consistent with national requirements;
— Consideration of siting possibilities and grid capacity;
— Consideration of the financial resources required for programme development in the next phases;
— Consideration of financing options, ownership options and operator responsibilities, including consideration of an electricity market structure that will provide adequate income to sustain safe and secure operation of an NPP;
— Recognition that there remains a non-zero possibility of a large radiological release and that the country will need to be able to manage the consequences.

The report should also include plans for the following:

— Joining the relevant international legal instruments;
— Developing a comprehensive legal framework;
— Having an effectively independent regulatory body;
— Developing the main elements of the required regulatory framework for safety, security and safeguards;
— Developing emergency response capability;

— Acquiring the required capabilities and human resources, including potential external support needs of the regulatory body and owner/operator;
— Ensuring the required financial resources for the programme development;
— Securing an electricity price through power purchase agreements or market regulation that ensures the long term financial viability of the owner/operator;
— Funding decommissioning and radioactive waste management;
— Ensuring domestic and international confidence by maintaining open, transparent and timely communication.

3.1.2. National position: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

Phase 2 starts with a decision to proceed with the development of a nuclear power programme. The government should, based on the Phase 1 comprehensive report, formally approve a specific proposed nuclear power programme and it (or the owner/operator) should decide on the strategy for developing contract arrangements for the NPP (e.g. competitive bidding, strategic partnerships, 'build–own–operate' or another alternative).

During Phase 2, the NEPIO then ensures that the approved programme policies and strategies are translated into firm action plans for each of the 19 infrastructure issues and that corresponding responsibilities are assigned to the organizations that will become permanent parts of the overall infrastructure. The relevant subsections of Section 3 give details of the actions to implement to develop specific infrastructure elements for each of the issues.

As noted in Section 2.2, what is important is that the NEPIO carries out its coordination functions and that its responsibilities are clear. It is recognized that this can be accomplished through various organizational arrangements.

In Phase 2, one key step is the development of an effectively independent regulatory body with all the necessary expertise and resources as well as responsibility for all regulatory matters needed for a nuclear power programme. This is addressed further in Section 3.7.2. A second key step is the designation of an owner[5] that will negotiate the specific contract with the supplier of the NPP at the beginning of Phase 3. This is addressed further in Section 3.3.2.

[5] The reference here to just the owner, rather than the owner/operator, reflects the possibility that a country may prefer that a sole supplier or strategic partner offer operating services as part of its proposals. In those cases, the 'operator' would only be established with the conclusion of the contract negotiations at the beginning of Phase 3.

3.1.3. National position: Phase 3 — Activities to implement the first nuclear power plant

To be ready to operate an NPP, the country should have established by the end of Phase 3 the infrastructure to operate and regulate the plant in compliance with national laws, national regulations and international commitments. This will include a competent regulatory body and a competent owner/operator for operating the NPP. The government should also have assigned to a specific agency, possibly the existing NEPIO mechanism or ministry of energy, the continuing responsibility for the government's role in the nuclear power programme.

Over the course of Phase 3, the NEPIO should ensure the overall development of the infrastructure to meet the national strategy. Areas requiring particular coordination across organizations include the following:

— Ensuring that the relevant legislation is maintained and amended, as appropriate;
— Ensuring that the owner/operator and the regulatory body are fully funded, staffed with competent personnel and provided with the necessary resources, and have assumed their responsibilities with full authority;
— Ensuring that all organizations give appropriate attention to nuclear safety, nuclear security and safeguards;
— Ensuring that grid developments are funded and implemented;
— Ensuring that emergency preparedness and response (EPR) plans are established and demonstrated;
— Ensuring that stakeholder engagement remains a priority;
— Ensuring that the financing and electricity market structure provide adequate income for safe and secure operations, and that mechanisms are available for compensation for nuclear damage;
— Ensuring that the human resource development programmes are sufficient to support continuing safe operation;
— Ensuring that responsibilities have been assigned and an appropriate funding plan has been implemented for waste, long term spent fuel management and decommissioning;
— Ensuring that mechanisms are in place for exchanging information with other nuclear power countries and providing mutual support.

As stated earlier, the need for strong government commitment and support continues well beyond the end of Phase 3. The government should establish mechanisms to ensure the long term sustainability of the programme and the maintenance of national commitments to nuclear safety, nuclear security and non-proliferation. Stakeholder engagement will continue to be essential, as

will ensuring that the knowledge gained from the first nuclear power project is available to any future nuclear power projects or related activities. The government will need to continue support for development of national waste management programmes.

3.2. NUCLEAR SAFETY

Nuclear safety requires commitments by all elements of the government, owner/operator, regulatory body, nuclear technology and equipment suppliers and other organizations to ensure safety in all aspects of the nuclear power programme. Most of the actions described in this publication have some impact upon safety.

Among the organizations, the owner/operator has a key role in safety since the international legal instruments and IAEA safety standards assign prime responsibility for safety to the operating organization as the holder of a licence for an NPP. It needs to develop its organizational and technical capability to meets its responsibility.

Experience has shown that while safety of NPPs has to be achieved primarily by design measures without relying excessively on human intervention, a robust design is by itself insufficient to ensure nuclear safety. Nuclear safety also requires effective leadership and management and an infrastructure that ensures vigilance and fosters a safety culture.

3.2.1. Nuclear safety: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

An integral part of becoming ready to make a knowledgeable commitment to a nuclear power programme is the recognition of the importance and priority of safety. Safety is a necessary component of all activities associated with planning and management of the siting, design, manufacture, construction, commissioning, operation and decommissioning of a nuclear power facility.

With respect to safety, the studies and report prepared by the NEPIO in Phase 1 should describe the following:

— The necessary elements of a national policy and strategy for safety;
— The principles of nuclear safety and general plant design requirements and how they are considered in current designs, including specific aspects of a nuclear power project when compared with conventional projects;
— Preparation for participation in the global nuclear safety regime;

— The commitment to implement the IAEA safety standards and to develop the national capabilities for nuclear safety and safety assessment;
— Plans for an effective legal and regulatory framework for safety, including an independent regulatory body;
— The establishment of effective leadership and management for safety, including the fostering of a culture for safety;
— Roles and responsibilities of key organizations in relation to safety during the different phases of the programme;
— The need for decommissioning and long term management of spent fuel and radioactive waste.

In addition to the importance of the legal and regulatory framework for a successful nuclear programme, the comprehensive report should stress that it is essential that a safety culture be developed within all organizations involved in the nuclear programme. A safety culture requires that all individuals involved in the programme recognize that safety is intrinsic to every aspect of the programme, accept personal responsibility for safety and perform all their activities with that responsibility in mind. This will require all individuals to have, depending on their functions, different levels of robust knowledge and understanding of safety aspects of siting, design and operation of the NPP.

Building an NPP implies a long term commitment to participate in the global nuclear safety regime. The country should plan to become a party to international instruments on nuclear safety (see Section 3.5) and to share knowledge and experience through information networks and participation in regional and international organizations. Early membership as a Contracting Party to the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention) (see Section 3.5), and active participation in the associated peer reviews will demonstrate commitment to the global nuclear safety regime.

The need for international cooperation and open exchange of information related to nuclear safety will be an essential element. The options for bilateral or regional cooperation and specific actions for cooperation will be analysed and started, especially with countries with an established nuclear power programme.

3.2.2. Nuclear safety: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

Following the decision to proceed with the development of a nuclear power programme, in Phase 2 all organizations contributing to the programme need to be established or expanded.

Senior positions in the regulatory body and in the owner/operator should be filled as early as possible in Phase 2 to provide leadership for safety and to enable planning and development of these organizations. The regulatory body and the operating organization should start developing and implementing effective management systems and should initiate programmes and practices to build a leadership and culture for safety in their respective organizations.

The government should establish its policy and strategy for nuclear safety to cover the planned nuclear power programme and extend it, as appropriate, to its current facilities and activities.

The regulatory body and the owner/operator should develop a detailed understanding of the IAEA safety standards. The intended strategy for developing safety regulations should be established early in Phase 2, as it may have an impact on the choice of nuclear reactor technology that is being considered for construction in the country. This should be supplemented by developing key safety requirements based on the IAEA safety standards, since those requirements would be needed for the bidding process / contract negotiations for the NPP.

Arrangements for communication about licensing and safety issues between the regulatory body, the owner/operator and the suppliers should be developed as needed and implemented by the regulatory body and the owner/operator (see Section 3.7.2).

3.2.3. Nuclear safety: Phase 3 — Activities to implement the first nuclear power plant

Phase 3 is a period in which the nuclear power project undergoes rapid development, progressing from the conclusion of the contract for supply of the NPP through initial licensing, construction and preoperational testing, up to the point of readiness for operation of the facility. The activities of the owner/operator and the regulatory body evolve during this phase, and their organization, staffing and competences must also evolve commensurately. The leaders of the owner/operator and the regulatory body need to exercise skill in managing growth and change while continuing to develop the knowledge and capabilities in all technical disciplines relevant to the safety of the NPP and to reinforce a culture for safety in their respective organizations.

The selection of proven NPP technology that has been previously licensed in the supplier country or in other countries creates the possibility for the regulatory body and owner/operator, in developing capability for safety assessments and facilitating the licensing process, to make use of the other regulatory bodies' experience, codes and standards. In this case, the regulations that are in place in the supplier country can further be used by the regulatory body in further developing its regulatory framework. The regulatory body and the owner/operator

should assess the applicability of these other countries' requirements and their compatibility with national safety requirements.

Although the deployment of smaller, standardized SMRs may reduce the costs and timeline for project implementation, the regulatory body and the owner/operator must still develop their organizations and safety infrastructure in line with the project schedule. This may necessitate these entities to achieve faster learning and develop their organizations more quickly to adapt to a possible shorter construction time.

From an early time in Phase 3, the owner/operator should maintain good communication with the regulatory body and, with the support of the supplier as appropriate, prepare all documentation required to apply for the necessary licences in accordance with regulatory requirements. The documentation should include a safety analysis report, as defined by the national licensing process, that demonstrates the safety of the plant.

The regulatory body is responsible for conducting an independent review of the owner/operator's safety analysis report to assess whether the proposed facility meets regulatory requirements for safety.

When regulatory authorization for construction has been granted, the operator must oversee construction, including the contractors' supply chain, participate in commissioning and develop the personnel and procedures to begin safe operation. The regulatory body will conduct a programme of regulatory inspections to verify that the licensee and its suppliers are complying with the conditions of the authorization.

The owner/operator and the regulatory body should continue to develop safety culture in their organizations as well as appropriate interfaces between safety, security and safeguards to ensure effective coordination.

The owner/operator should also establish mechanisms to maintain the knowledge of the safety of the design and its configuration management over the lifetime of the plant. In addition, it is suggested that the owner/operator maintain a long term relationship with the NPP supplier to support safe operation in both normal and emergency situations.

Other responsibilities for the regulatory body in Phase 3 are summarized in Section 3.7.3.

3.3. MANAGEMENT

The roles and responsibilities of management will change as the process of developing a national nuclear power programme progresses from consideration to implementation and to operation. Management of a nuclear power programme is demanding, and highly competent managers are vital to success at all stages.

Effective management entails strong leadership, management systems, project management, strategy and planning, organization and competence development.

3.3.1. Management: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

The NEPIO will need the expertise necessary to address all 19 infrastructure issues and to develop the comprehensive report that supports the national position (see 3.1.1). While gaps in the necessary expertise can be filled by consultants, leadership responsibility and accountability should remain with national institutions.

The comprehensive report should emphasize that for the programme to succeed, it is essential that each organization with responsibilities for implementation of the programme develop plans for the implementation of management systems and for the development of leaders. The comprehensive report should also identify the leadership roles required to regulate a nuclear power programme. This is addressed further in Section 3.7.1.

It is important that the experience of the leaders of existing regulatory bodies, utilities and other major projects be taken into account in identifying management developments required to plan, procure, construct, operate and regulate an NPP.

It is important also that the knowledge gained on management issues during the Phase 1 comprehensive study be shared. Those in the NEPIO or engaged by the NEPIO in Phase 1 should ensure the transfer of this knowledge to the future regulatory body and future owner/operator. While it is difficult for the NEPIO to develop organization specific plans, it can ensure that it provides to each of the future organizations the key elements of the strategy for developing leadership skills and management systems that promote a safety and security culture. One approach can be to include a core group of future leaders within the NEPIO who then move into the key organizations at the appropriate time. They may also benefit from secondments to countries with existing nuclear power programmes.

3.3.2. Management: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

In Phase 2, the owner/operator should be designated and should begin to implement the defined strategy for the first NPP. The NEPIO should define the strategy for developing contract arrangements for the NPP. The owner/operator may be part of this process, but once it has been decided, the owner/operator

needs to develop an organization with the required competence to implement the strategy. Key actions include the following:

— Define an organizational structure and recruit appropriate staff.
— Establish an integrated management system.
— Develop, in conjunction with the NEPIO, a financing strategy, a contracting strategy, a fuel supply strategy and a spent fuel and radioactive waste management strategy (see Sections 3.4.2 and 3.16.2).
— Establish the arrangements necessary to proceed with procurement of the NPP (see Issue 19).
— Begin staff training to create a safety and security culture.
— Request information from potential technology providers and assess which are most appropriate or preferred.
— Complete site selection, site assessment and environmental impact assessment (EIA) studies (see Sections 3.12.2 and 3.13.2).
— Implement a stakeholder engagement programme (see Section 3.11.2), especially with respect to candidate sites.
— Build project management capabilities and a competent procurement team, recognizing that different contracting approaches (e.g. turnkey, split package) will require different levels of competence. Also, the manufacturing and construction arrangements for some SMRs may impact the project management capabilities needed.
— Establish a working relationship with the regulatory body.
— Train staff and establish a project management organization that will emphasize quality management and be able to ensure that all contract requirements are fully met.
— Institute procedures to ensure that knowledge critical to safe and secure operation will always be preserved.

For many of these activities, the national strategy may have already defined the high level decisions and, in that case, the NEPIO will look to confirm that the detailed implementation is in accordance with the national strategy. The NEPIO should also ensure that the rationale for the national decision to introduce nuclear power is well understood by all stakeholders.

There are existing and proposed owner/operator arrangements where the owner and the operator are separate entities. Detailed arrangements in such cases will depend on the legal and regulatory regime, the allocation of liabilities and the need to demonstrably meet regulatory requirements for licensees. If this arrangement is being considered, then towards the end of Phase 2 and early in Phase 3 it is essential that responsibilities and requirements for funding and competence development be clearly established. It should be clear

which organization will be the 'licensee' for siting, construction and operation. The responsibilities with respect to nuclear safety, nuclear security and non-proliferation should be clearly documented.

The government, during Phase 2, should ensure that relevant government agencies expand their capabilities to be ready to handle expanded demands for managing, for example, environmental protection, immigration, import and export controls, and EPR.

The regulatory body should establish management systems and take the additional associated steps described in Section 3.7.2.

3.3.3. Management: Phase 3 — Activities to implement the first nuclear power plant

The government has several responsibilities in Phase 3 — for example, handling finance and tax issues, providing environmental oversight, and managing trade and immigration — which will be distributed to appropriate government ministries.

The steps to be taken by the regulatory body in Phase 3 are addressed in Section 3.7.3.

For a country using competitive bidding, the owner/operator should begin Phase 3 by inviting bids, evaluating the bids received and selecting the winning bid(s) in accordance with the bid evaluation criteria. The subsequent activities listed below apply both to countries using competitive bidding and to countries using alternative approaches. Specifically, the owner/operator should carry out the following steps:

- Negotiate the contract(s) consistent with the contracting strategy developed in Phase 2.
- Obtain financing consistent with the financing strategy and the contract[6].
- Prepare a licence application in compliance with the regulatory requirements.
- Initiate and manage the construction contract, including appropriate contract oversight to verify compliance.
- Complete construction and apply for a licence/authorization to operate the plant.
- Establish mechanisms for handover of equipment and systems from the main supplier to the owner/operator.
- Develop the capability for safe and secure operation, including recruiting and training staff, establishing a design authority capability, obtaining

[6] Financing and contracting are closely linked with the allocation and management of financial risk identified in the contracts. Further discussion on financial risks is in Section 3.4.2.

licences and obtaining certifications as required for any needed external maintenance and support organizations.
— Establish working relationships with international and professional organizations related to nuclear power, for example the World Association of Nuclear Operators (WANO), who provide 'Performance Objectives' and 'accompanying criteria' together as a benchmark for successful safe and reliable operation.
— Develop procedures for event reporting.
— Contract for a continuing fuel supply.
— Maintain support from stakeholders for the operation of the plant.

In Phase 3, the owner/operator becomes a project management organization, managing construction oversight and preparing the licence applications. At the same time, it needs to develop the organizational arrangements required for operation and recruit and train the staff needed for commissioning and future operation. The organizational structure and management systems for operation will be significantly different to that for the construction phase and it is essential that the owner/operator manages this transition well.

By the end of Phase 3, the owner/operator must be capable of assuming full responsibility for safe and secure operation in accordance with national laws and regulations that take into account internationally accepted norms and standards. While this requirement remains for any NPP, the number of staff required and hence the complexity and size of the training programme may be significantly smaller for some SMR designs.

It is important that the NEPIO continue undertaking the following:

— To maintain momentum and to provide a continuing forum for communication and cooperation among the important organizations;
— To ensure that the roles of the key organizations (i.e. the government, regulatory body and owner/operator) are well defined and understood by all stakeholders;
— To ensure that the key organizations develop in line with the project schedule;
— To ensure that the rationale for the national decision to introduce nuclear power is also well understood by all stakeholders;
— To ensure that decisions made throughout Phase 3 remain consistent with the country's economic development strategy and the joint interests of the important parties;
— To support the development of programmes for the sustainability of the nuclear power programme in the long term.

3.4. FUNDING AND FINANCING

The funding and financing requirements for a nuclear power programme overall, and an NPP specifically, are very large. In this publication, 'funding' refers to items that are the responsibility of the government (e.g. ensuring resources for developing regulations, initial development of the owner/operator organization). 'Financing' refers to the raising of capital required to construct the NPP and the establishment of an income stream to support long term safe operation and service the debt and equity arrangements.[7]

Initial *funding* for infrastructure development will likely come from government sources. Specific items that will require government funding are listed in Section 3.4.1, such as the development of human resources and the establishment of the legal framework. A demonstrated, continuing government commitment to funding all the areas outlined in this subsection will be important in developing the confidence of the financial community to invest in the plant.

Financing for the first NPP can be pursued in a number of ways, and a typical financing structure for a project will include both debt and equity finance from several sources, including probably the host government. However, the viability and extent of such financing will depend on the country's overall economic situation, and the potential for such financing may be severely limited for some countries.

Export financing is typically a significant source of debt financing for an NPP. However, export financing will still cover only part of the overall investment, even though that part may be substantial.

Local or foreign commercial debt financing may also be needed, possibly encouraged by specific government guarantees. Such guarantees may be direct (e.g. a guarantee to lenders that their loans will be repaid) or indirect (e.g. power purchase agreements or electricity market regulation to guarantee sufficient revenue from electricity sales). Perceived creditworthiness will be very important if the government's direct or indirect guarantee is to benefit the project. The country's economic policy, debt management and legal risk sharing mechanisms are all important to creditworthiness. Some countries have negotiated an intergovernmental agreement with the supplier country to provide an overarching agreement on the development of a nuclear power programme. This can be used to address some of the financing guarantees discussed above.

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[7] Funding and financing sometimes intertwine. For example, if the regulatory body is to be funded partly by fees from the owner/operator, the owner/operator will need to finance these fees through electricity sales. Similarly, the costs of long term storage and disposal of radioactive waste, or of decommissioning, may be covered by building up *funds* that would be *financed* by small percentages of the revenues from electricity sales, rather than *funded* from the government's general revenues.

A country may seek to reduce the extent to which it must provide financing by engaging local or foreign equity partners who invest directly in the project in exchange for a share in the owner/operator profits or electricity supplied at an agreed price. A foreign equity partner may also supply expertise to the owner/operator; such a partner is often referred to as a strategic partner. An arrangement in which the country seeks a foreign company or consortium to build, own and operate the plant is a type of partnership arrangement.

With any partnership, the country would still have significant funding responsibilities (e.g. for its regulatory body and emergency preparedness), and it might be required to cover some financial risk through, for example, a power purchase agreement or loan guarantees. Strategic partnership arrangements would be more likely to involve direct negotiations with selected suppliers than the solicitation of competitive bids and could require agreements with the partners' respective governments.

3.4.1. Funding and financing: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

The prefeasibility study conducted by the NEPIO in Phase 1 should review all relevant funding requirements and financing options.

Regarding *funding*, the study should recommend how the following activities will be funded:

— Establishment of the legal framework;
— Establishment of the regulatory body for safety, security and safeguards;
— Establishment of the owner/operator organization prior to the start of receiving income from electricity generation;
— Planning and implementation of the government's stakeholder engagement programme;
— Siting and environmental protection activities that are the responsibility of the government (see Sections 3.12 and 3.13);
— Establishment of the EPR system;
— Development of education, training and research programmes;
— Improvements to the electrical grid (if such improvements are the government's responsibility);
— Establishment of any proposed incentives and direct government support to promote localization;
— Establishment of spent fuel and radioactive waste management systems, including storage and disposal;
— Decommissioning.

Studies have been carried out to estimate the funding needed to develop the required nuclear infrastructure. The total resources (excluding hardware costs such as grid enhancements and site preparation) have been estimated in the order of 5–10% of the cost of a contract for 2 units of 1000 MW(e). Approximately 15% of this is required during Phase 2 and over 80% during Phase 3 (largely in the owner/operator organization). While some of this resource cost can be factored into a feasibility cost model and recovered through the cost of electricity produced, it is important to recognize that all these resources will need to be funded before any electricity is produced.

Regarding *financing*, the NEPIO's recommendation should identify potential options together with financial and risk management strategies that together (a) create sufficient confidence for lenders and investors to support an NPP project and (b) ensure the long term viability of the owner/operator to fulfil all its responsibilities. Even if the recommendation does not include the government as a direct sponsor of the project, it should address the government's role in reducing financial risks. This should include the role of the government in ensuring a secure revenue stream as well as its role in securing the required debt and equity for the project.

3.4.2. Funding and financing: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

During Phase 2, on the basis of the information in the comprehensive report, more specific *funding* plans for the items listed in Section 3.4.1, and for covering Phases 2 and 3, should be developed by the government, the regulatory body and the owner/operator, with appropriate coordination by the NEPIO. For Phase 2 itself, resource intensive activities include establishing the legal and regulatory framework, carrying out siting studies and establishing and developing the key organizations. For Phase 3, resource intensive activities including recruiting and training staff for operations, overseeing the construction contract and preparing and reviewing licence applications.

Regarding *financing*, the complexity of obtaining financing for the first NPP will require significant expertise. During Phase 2, the financing plan for the NPP project should be established together with a strategy for managing associated financial risks. The principal responsibility for this should likely lie with the owner/operator, but the government also has a key role to play. This is likely to be an iterative process as organizations (i.e. owner/operator, government and potential investors and lenders) seek to develop a viable financing strategy.

Controlling the cost of financing will require attention to many issues. Financing sources seek a return on their loans or investments and confidence in

their capital recovery over a reasonable period. This is true for both public and private financing, although public financing may have a higher risk tolerance than private financing. However, common to both approaches is the control of risk.

Nuclear power carries some unique and significant financial risks. There are risks of significantly increased costs because of construction delays, regulatory delays, and delays from public intervention. There are risks of reduced income from possible operational difficulties or changes in the electricity price — if it is not guaranteed in a power purchase agreement or by market regulation. Because of the long period required to recover investment costs, these could result in low, or negative, returns on the original investment. In addition, there is the risk of liability arising from a nuclear accident, which needs to be mitigated by adherence to appropriate international instruments and national insurance arrangements.

A successful financial plan should consider the country's susceptibility to these risks, allocate the management of each risk to the most appropriate organization, consider how to minimize such risks and, should delays arise nonetheless, determine how any cost overruns will be financed. Factors that are important to financial institutions include the political and economic stability of the country, degree of stakeholder engagement, prospects for continued economic development, protection of foreign investment, promulgation of legislation conducive to nuclear power, existence of a competent operator and regulatory body and capability to manage large capital construction projects. Particularly important considerations for the government in making the country's financial environment attractive to potential lenders and investors include the following:

— A strong policy in support of nuclear power;
— Established creditworthiness;
— Good stakeholder engagement to foster sufficient public support;
— A complete legal and regulatory framework to support both the safe, secure and peaceful use of nuclear power and the financial guarantees necessary for the chosen financial approach;
— A competent, effectively independent regulatory body with secure continuous funding;
— Effective nuclear security and safeguards programmes with secure continuous funding;
— A commitment to developing national expertise and human resources to support a long term commitment;
— Plans to fully cover the costs of decommissioning, and the costs of long term management and disposal of spent fuel and radioactive waste;
— A structure for electricity tariffs that is sufficient to ensure a return on capital investment.

3.4.3. Funding and financing: Phase 3 — Activities to implement the first nuclear power plant

The necessary funding must be ensured for the regulatory body, including funding for consultancy support for assessment and inspection activities, and for the government's responsibilities with respect to stakeholder engagement, safeguards, environmental protection, human resources development, improvements to the electrical grid and incentives for localization. Since the owner/operator revenue flow can only start when the NPP starts generating electricity, significant funding will need to be provided to the owner/operator to allow oversight of construction and staff recruitment and training for operation. It is also important that the operator have insurance to cover a nuclear accident in place before the nuclear fuel is transported to the reactor site.

By the end of Phase 3, mechanisms must be implemented to secure funding for long term spent fuel and radioactive waste management, including disposal, and for decommissioning. The government should also consider mechanisms to fund programmes to ensure the long term sustainability of the nuclear power programme (e.g. research programmes).

Regarding *financing*, most important in this phase will be the agreement about the financing arrangements based on the contract and financing negotiations. It will also be important that there be a high level of confidence that electricity tariffs will be sufficient to ensure both a return on capital investment and the safe operation of the plant. If support for financing was part of the competitive bidding process, the evaluation of proposed financing arrangements will be a key aspect of the owner's[8] evaluation of bids at the beginning of Phase 3.

3.5. LEGAL FRAMEWORK

The national legal framework for nuclear power should comprehensively cover all aspects of nuclear law; that is, nuclear safety, nuclear security, safeguards and civil liability for nuclear damage. Experience shows that many countries embarking on a new nuclear power programme establish a comprehensive law addressing nuclear safety, nuclear security, safeguards and, in some cases, nuclear liability. The national legal framework should implement international legal instruments in these areas to which the country is a party or intends to become

[8] The reference here to just the owner, rather than the owner/operator, reflects the possibility that a country may prefer that a sole supplier or strategic partner offer operating services as part of its proposals. In those cases, the 'operator' would only be established with the conclusion of the contract negotiations at the beginning of Phase 3.

BOX 1: RELEVANT INTERNATIONAL LEGAL INSTRUMENTS ADOPTED BY AND UNDER IAEA AUSPICES

— Convention on Early Notification of a Nuclear Accident (INFCIRC/335);
— Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (INFCIRC/336);
— Convention on Nuclear Safety (INFCIRC/449);
— Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (INFCIRC/546);
— Convention on the Physical Protection of Nuclear Material (INFCIRC/274) and Amendment thereto (INFCIRC/274/Rev.1/Mod.1/Corr.);
— Vienna Convention on Civil Liability for Nuclear Damage (INFCIRC/500);
— Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage (INFCIRC/566);
— Convention on Supplementary Compensation for Nuclear Damage (INFCIRC/567);
— Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention (INFCIRC/402)[a];
— Comprehensive safeguards agreements — based on The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/153/Corr.);
— Additional protocols — based on the Model Protocol Additional to the Agreement(s) Between States(s) and the International Atomic Energy Agency for the Application of Safeguards (INFCIRC/540/Corr.);
— Revised Supplementary Agreement concerning the provision of Technical Assistance by the IAEA.

[a] The Convention on Third Party Liability in the Field of Nuclear Energy (Paris Convention) is another relevant legal instrument, adopted under the auspices of the Organisation for Economic Co-operation and Development (OECD).

a party. Box 1 lists the international instruments adopted by and under IAEA auspices that are relevant to the establishment of a nuclear power programme. These instruments are relevant both to programmes based on conventional NPPs and SMRs. The national legal framework also includes all additional legislation that may affect the nuclear programme.

The legislation should be consistent with national legal practices, institutions, and economic circumstances; level of technological development; and cultural values. It should establish the responsibilities of all organizations necessary for a successful nuclear power programme. Experience has proven that safety and credibility are best served by institutionally separating the enabling and regulatory aspects of nuclear power. The legislation should make the regulatory body functionally separate from, and effectively independent

of, all entities (including parts of the government) that have responsibilities or interests that could unduly influence its safety related decision making or that promote the development of the nuclear industry. The legislation should provide the regulatory body all necessary legal authority, technical competence and resources to independently fulfil its statutory obligation to regulate facilities and activities in an effective manner, and to be free from undue political, technical and economic influence.

During the development of the legal framework for a nuclear power programme, the government should make use of the experience and knowledge gained in developing and implementing existing infrastructure for nuclear safety, radiation safety and the security of radioactive sources that covers the country's existing facilities and activities, including radioactive waste management and the transport of radioactive material.

It is also important to consider the relationship of the nuclear law with other existing laws while preparing the legislation. Since nuclear law is a specialized field, professional input from relevant experts is essential to formulate appropriate legislation.

3.5.1. Legal framework: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

A fundamental understanding of the requirements for a legal framework should be developed by the NEPIO and discussed with the appropriate government institutions. The knowledge and experience of the regulatory body for the control of radiation sources and other applications of ionizing radiation will be valuable, and the existing legal framework for radiation safety, security and emergency response should also be considered. Some countries may also have experience with research reactors or nuclear fuel cycle activities that require establishing certain elements of the legal framework for nuclear activities. This needs to be expanded to meet all the requirements of having NPPs in the country. An understanding of the relevant international legal instruments and their implications for national legislation will be needed.

The NEPIO's comprehensive Phase 1 report should describe the schedule for adherence to relevant international instruments listed in Box 1. In addition, the report should highlight the need to put in place legislation to establish an effectively independent regulatory body with adequate human and financial resources and a system of authorization, inspection and enforcement. Where several authorities have responsibilities for safety, the responsibilities and functions of each authority should be clearly specified in the legislation. The legislation should clearly delineate the responsibilities of all authorities involved in the nuclear power programme and cover all areas of nuclear law,

for example radiation protection; the safety and security of nuclear facilities and radioactive material EPR; mining and milling, if appropriate; transport of radioactive and nuclear materials; radioactive waste and spent fuel management; decommissioning; nuclear liability; safeguards; and export and import controls.

Finally, the report should also identify all additional legislation that may affect the nuclear programme, including legislation which would need to be enacted or amended. This could include, for example, legislation on environmental protection, EPR, occupational health and safety, foreign investment, financial guarantees or other financial legislation.

3.5.2. Legal framework: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

During Phase 2, the country should enact comprehensive national legislation, as outlined in Section 3.5.1, covering all aspects of nuclear safety, nuclear security, safeguards and civil liability for nuclear damage. Prior to inviting bids or defining contract specifications for the first NPP, it should also identify and put in place all legislation that may affect the nuclear power programme. Failure to do so significantly increases the risk of subsequent costly delays. Because nuclear legislation is complex and specialized, the country should be sure to allow sufficient time and devote sufficient resources to completing it on schedule.

In addition, during Phase 2, the country should take the necessary steps to adhere to the international legal instruments in Box 1.

3.5.3. Legal framework: Phase 3 — Activities to implement the first nuclear power plant

By the beginning of Phase 3, comprehensive nuclear legislation and all other legislation that may affect the nuclear power programme should be in force, together with mechanisms to ensure compliance. During Phase 3, all actions to implement the relevant international legal instruments should be completed. The legal framework should be maintained, reviewed and amended as necessary during the lifetime of the nuclear power programme. An action plan should be in place to address any identified issues with the legal framework and to enable its amendment as necessary.

3.6. SAFEGUARDS

There are a number of international legal instruments, treaties and agreements, such as the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) or regional treaties establishing nuclear-weapon-free zones, under which parties undertake to accept IAEA safeguards. In non-nuclear-weapon States party to the NPT, safeguards measures are to be applied under a comprehensive safeguards agreement (CSA), in connection with the NPT, to all nuclear material in all peaceful nuclear activities within the State's territory, under its jurisdiction or carried out under its control anywhere. The objective of IAEA safeguards under a CSA is the timely detection of diversion of nuclear material from peaceful nuclear activities to nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection.

A country contemplating a nuclear power programme should be prepared to meet the safeguards obligations that would apply to such a programme. It should have a clear understanding that, with the introduction of nuclear power, there will be a substantial jump in the capabilities required to meet its safeguards obligations. The size of the jump will partly depend on the country's technological and fuel cycle choices (e.g. plans for the type and number of reactors, options for the front and back ends of the fuel cycle, whether refuelling is on-line or off-line). There should also be an understanding of the additional responsibilities that may be associated with the control of import and export of nuclear items and nuclear material associated with the proposed NPP.

In order to exercise the required State control and to facilitate cooperation with the IAEA in implementing the provisions of its CSA and additional protocol (AP), the country should establish and maintain an effective State system of accounting for and control of nuclear material (SSAC). It is an obligation under the CSA to establish and maintain the SSAC, irrespective of the amount of nuclear material or the extent of nuclear applications in the country. Establishing an SSAC includes designating, as part of the country's nuclear law, the responsible regulatory body and defining its safeguards responsibilities. Making the regulatory body for safety and/or security also responsible for the SSAC offers potential synergies.

3.6.1. Safeguards: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

Non-nuclear-weapon States that are party to the NPT are required to bring into force a CSA based on INFCIRC/153 (Corrected) and associated subsidiary arrangements. Many countries with a CSA have also concluded an additional

protocol on the basis of INFCIRC/540 (Corrected), which equips the IAEA with important additional tools that provide broader access to information and locations in the State and significantly increase the IAEA's ability to verify the peaceful use of all nuclear material in the State. The country should be aware of the obligations of the AP and, if it intends to conclude one if it has not already done so, a plan should be in place by the end of Phase 1 for timely conclusion. The CSA and the AP contain specific rights and obligations undertaken by the country and the IAEA to provide for the effective implementation of safeguards.

Many States that do not have any nuclear facilities have concluded small quantities protocols (SQPs), which have the effect of temporarily suspending many of the safeguards procedures of the CSA. However, if the country currently has an SQP in force, by the end of Phase 1 it should set out a plan for rescinding the protocol in a timely manner. The recission of the SQP will have implications for all entities that possess and use nuclear material in the State. The implications include additional procedures for nuclear material accountancy, provision of early design information for the facilities to be constructed and other safeguards related information to the safeguards regulatory authority, and access by IAEA inspectors to carry out in-field verification activities.

The NEPIO's comprehensive report at the end of Phase 1 should cover the country's additional efforts that will be needed with the introduction of nuclear power to ensure the following:

— Cooperation between the State, facility operator, supplier/designer and the IAEA in safeguards implementation;
— Completeness and correctness of the State's declarations in order to ensure effective independent verification by the IAEA;
— Preparations by entities involved in the programme to meet their reporting obligations to the designated regulatory body.

3.6.2. Safeguards: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

In the preliminary stages of the development of a nuclear programme, the SSAC and its regulatory oversight might involve only one or two individuals, whose primary objective would be to provide information to the IAEA and to implement activities required by the applicable safeguards agreement (e.g. early provision of design information to the IAEA). The country should consider including in the bid invitation or contract specifications requirements on safeguards design features that would facilitate effective safeguards implementation. The integration of safeguards into the design process may also

reduce facility life cycle costs by reducing the potential need to accommodate safeguards activities through costly retrofits or workarounds. It may also allow the facility designer to capture efficiencies by addressing related safeguards, security and safety requirements through an optimized design process. It also fosters a culture where safeguards, security and safety are treated as 'full and equal' partners in the design process.

As the nuclear programme progresses, the SSAC's organizational and functional responsibility should be developed as required for the country to effectively fulfil its safeguards obligations, including the following:

— Assignment of responsibilities for safeguards activities and the granting of legal authority to perform them to an independent regulatory body;
— Implementation of procedures and practices necessary to facilitate information gathering, timely reporting and in-field verification;
— Creation of an effective communication mechanism, including a point of contact between the IAEA and the State on safeguards matters.

In addition, the terms of all international and regional instruments to which the government is a party, or intends to become a party, should be examined to ensure that the national legislation is consistent with the obligations in those instruments. The country may need to prepare new legislation, rules, regulations and procedures. For example, development of the nuclear power programme may require adjustments in the country's import–export controls. Plans for the effective implementation and enforcement of such legislation should be completed during Phase 2.

If a country plans to develop enrichment, fuel fabrication or reprocessing capabilities, it should provide, under the CSA, early design information and, under the AP, information on its general plans relevant to the development of the nuclear fuel cycle to the IAEA.

3.6.3. Safeguards: Phase 3 — Activities to implement the first nuclear power plant

During Phase 3, the implementation of safeguards starts in earnest with the preparation for operation of the NPP and the planned introduction of nuclear fuel to the facility. The regulatory body and the operator must complete the establishment of the SSAC, for example by recruiting and training the needed staff and finalizing procedures for the accounting for and control of nuclear materials and establishing reporting mechanisms. The interfaces between safety, security and safeguards should be optimized for NPP operation.

The IAEA will work closely with the regulatory body and facility personnel to verify the initial report on nuclear material and the design information provided in the initial design information questionnaires and subsequent reports, to install equipment for containment and surveillance and to put clear communication mechanisms in place for the fulfilment of all safeguards obligations under the agreement between the country and the IAEA. All elements of the safeguards infrastructure at the facility should be in place and verified prior to the receipt of fuel at the NPP.

3.7. REGULATORY FRAMEWORK

A competent, effectively independent, well resourced nuclear regulatory body that has the strong support of the government is crucial to the long term success of a national nuclear power programme and the confidence of the public and international community. Experience has shown, however, that the development of the regulatory body in some countries has lagged in the implementation of the overall programme. The accelerated schedule offered by new technologies such as SMRs presents a further challenge. Therefore, the development of the regulatory body should be given high priority by the NEPIO, either as a new regulatory body or as an extension of an existing regulatory body. The development of leadership and competent human resources is as important for the regulatory body as it is for the owner/operator. The technical capabilities of the regulatory body should be sufficient for assessing nuclear and radiation safety, security and safeguards issues and verifying compliance in all relevant aspects of the nuclear power programme.

The structure of the regulatory body for the oversight of a nuclear power programme varies from country to country and may reflect the country's existing regulatory framework for the regulation of radiation sources and radiological facilities. Case studies show that many countries embarking on a new nuclear power programme have created an independent regulatory body with responsibilities for nuclear and radiation safety, security and safeguards, taking advantage of the synergies among these three areas, also referred to as the '3S's'. However, some countries operating NPPs have different regulatory bodies with responsibility for nuclear security and safety or safeguards. To cover these different arrangements, and as noted earlier, statements about the 'regulatory body' should generally be understood as dealing with the 'regulatory body or bodies'.

As noted in Section 3.5, experience proves that safety and credibility are best served by institutionally separating the enabling and the regulatory aspects of nuclear power. However, separation does not mean that the regulatory body should not take part in the communication, engagement and cooperation fostered by the NEPIO for developing the infrastructure for a nuclear power programme;

any existing regulatory body should be represented in the NEPIO in Phase 1 and, in subsequent phases, the regulatory body should continue to be part of the programme coordination mechanism organized by the NEPIO while maintaining its full independence.

Countries introducing nuclear power may consider building on the infrastructure already in place for radiation safety and nuclear security while recognizing that regulating nuclear power is significantly more complex than regulating radiation sources. Expanding an existing regulatory body to cover nuclear power may be a more efficient use of resources — particularly human resources — that are likely to be limited in many countries. In any case, the regulatory body will have new and more complex responsibilities associated with the nuclear power programme that require the establishment of new processes and procedures and the acquisition of additional competences.

3.7.1. Regulatory framework: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

The NEPIO's recommendations at the end of Phase 1 should include plans to develop a regulatory framework in Phase 2 on a timeline that matches the proposed nuclear power programme and takes account of the existing regulatory framework for radiation safety and nuclear security. The fundamental elements of a regulatory framework that should be established through the national legislation include the following:

- Designation of an effectively independent competent regulatory body with clear authority, adequate human and financial resources and strong government support;
- Assignment of core regulatory functions for developing regulations, review and assessment, authorization, inspection, enforcement and communication/consultation with the interested parties;
- Authority and resources to obtain technical support as needed;
- A clear definition of the relationship of the regulatory body to other organizations;
- Clearly defined responsibilities of licensees, including prime responsibility for safety;
- Authority to implement international obligations, including IAEA safeguards;
- Authority to engage in international cooperation;
- Provisions to protect proprietary, confidential and sensitive information;
- Provisions for communication and consultation with interested parties.

In developing its recommendations, the NEPIO should ensure communication and cooperation among all important parties, including the country's major utilities, relevant government agencies, the public, legislative representatives and other decision makers. As the regulatory body will need to be established early in Phase 2, prospective senior managers should be identified in Phase 1.

3.7.2. Regulatory framework: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

Early in Phase 2, the main priority is the establishment of the regulatory body, with functions in line with the national legislation, as enacted by the legislative body. The leadership of the regulatory body will need to focus on the following tasks and elements:

— Overall organization, staffing and training;
— Establishment and implementation of a management system within the regulatory body, for the delivery of its core responsibilities, and the necessary support functions;
— Development of a safety and security culture in the regulatory body;
— Communication and consultation with the interested parties;
— Establishment of technical support arrangements and international relationships with other regulatory bodies to, among other things, expand the technical support available to the regulatory body;
— Regulations, guides and standards that govern the management of safety, site evaluation, design (including decommissioning aspects), construction and manufacturing by including them in the bidding process or contract negotiations;
— The formal licensing process;
— The oversight process for regulated activities and associated enforcement actions.

At this stage the regulatory body should focus on the products and services needed for the initial activities in the nuclear power programme. The framework will ultimately need to cover all phases of the programme, including operation, decommissioning and spent fuel and radioactive waste management, but some of these aspects may be covered by future work plans.

By the end of Phase 2, sufficient competent staff should be in place with adequate financial resources to carry out the following:

— License or approve sites.
— Review, assess and license nuclear plant designs and/or project activities and make safety, safeguards and security decisions as called for in the national legal and regulatory framework.
— Oversee nuclear construction and to enforce compliance with regulations.
— Ensure sufficient communication and consultation with the public and other stakeholders.

The regulatory body should have plans to augment its staff as necessary to reduce its dependency on external experts in the long term.

The regulatory body should establish a licensing system and should develop and/or adopt regulations and guides necessary to inform the contracting arrangements and to cover the initial licensing phases. The set of regulations to fully support a nuclear power programme is extensive. Throughout Phase 2, the regulatory body should have a firm strategy for prioritizing the development of regulations. Regulations that could have an impact on the choice of technology should be established early in the process. Regulations governing the management of safety, site evaluation, design (including decommissioning aspects), construction and manufacturing should be prepared and included in the bidding process or contract negotiations. In setting its requirements, the regulatory body may adopt IAEA safety standards as a reference and may complement these with a well established set of requirements that are in use in States with extensive experience of NPP operation, in particular the vendor country. If the regulatory body decides on this complementary option, the entire set of standards should be carefully reviewed to avoid conflicts, inconsistencies or incompleteness.

The regulatory body should establish mechanisms with all stakeholders for open and transparent communication. The regulatory body and the owner/operator should develop and implement a protocol for communication about licensing and safety, security and safeguards issues between the regulatory body, the owner/operator and the suppliers. This should include arrangements for the transmittal of information, correspondence, agreement of actions and formal meetings at a range of levels of seniority.

3.7.3. Regulatory framework: Phase 3 — Activities to implement the first nuclear power plant

The activities performed by the regulatory body evolve throughout Phase 3 in response to the implementation of the NPP project. The regulatory activities

include initial assessment and licensing of the NPP construction, then oversight of construction and pre-operational testing, then authorizing commissioning and operation. It is important to recognize that the leadership of the regulatory body must deliver the regulatory functions needed at each step and manage, at the same time, growth and change in the organization to prepare for the activities needed in the subsequent steps. During Phase 3, the regulatory body should continue to develop its regulatory framework, staffing and procedures for the operational phases.

Early in Phase 3, all regulations, guides and standards for nuclear facility construction should be in place. If a country is only considering a single reactor design, it may be helpful, if appropriate for the adopted regulatory approach, to elaborate existing regulations or to develop additional regulations based on the regulations of a country that has mature experience with that design, in particular the vendor country. The advantages of this approach are that the buyer country's regulatory body might be able to finalize its regulations more quickly, the supplier would already be familiar with these regulations, and there is the possibility of knowledge transfer regarding safety assessments. If a country chooses to adopt the regulations of another country in whole or in part, then it is essential that the country fully understand these regulations and is competent to implement them. It should adapt the regulations to reflect specific national requirements and to ensure that the IAEA safety standards are adequately incorporated. At this stage, staffing at the regulatory body should be sufficient to efficiently license the NPP and provide regulatory oversight of the activities authorized by the licence.

Once the NPP supplier has been chosen, the regulatory body should consider cooperation with the regulatory body in the vendor country and in other countries that have regulated similar plants. This cooperation may cover the transfer of knowledge regarding training and development of staff and safety assessments performed for a similar reference plant.

Prior to the fuel arriving on site, the regulatory body should have staffing and infrastructure in place for carrying out its emergency response role.

Regulatory requirements for operator training and certification should have been developed, and the regulatory body should confirm that the licensee has demonstrated compliance.

The regulatory body's plans to maintain competent staff and develop future staff should be in place. Open communication with appropriate stakeholders, including the government, the owner/operator, the public and international organizations, should be well established.

Prior to commencement of commissioning of the NPP, the regulatory body should issue regulations or guides to specify issuance of appropriate licences/approvals and describing submissions to be made by the operator as part of independent oversight by regulatory body for the commissioning. By the end of

Phase 3, the regulatory body should have developed comprehensive programmes for inspection, and competent staff should be in place to provide regulatory oversight of the operation and maintenance of the plant to verify that the licensee is conducting its activities in accordance with regulatory requirements and licence conditions, and, where necessary, enforcing compliance.

3.8. RADIATION PROTECTION

Radiation protection refers to the protection of people and the environment from harmful effects of exposure to ionizing radiation, and the means for achieving such protection. Radiation exposure may be planned or unplanned and may involve workers (through occupational exposure), members of the public and the environment. Various complementary measures contribute to radiation protection, including measures to control the exposure of people, measures to restrict the likelihood of events that might lead to the loss of control over a nuclear reactor or other radioactive source, and measures to mitigate the consequences of such events if they were to occur. The system of protection and safety aims to assess, manage and control exposure to radiation so that radiation risks are reduced to a reasonably achievable extent. There is a significant overlap between the concepts of radiation protection and nuclear safety, and it is important that all organizations manage this interface effectively. For a nuclear power programme, minimizing the risks and/or accidental exposure is usually addressed through a nuclear safety assessment.

As noted in Section 2.2, because there could be medical, industrial and research applications of ionizing radiation prior to introducing or expanding a nuclear power programme, a country may have an existing national infrastructure for nuclear and radiation safety in place. While the radiation protection aspects of a nuclear power programme require additional consideration, it may best be addressed by expanding the existing infrastructure.

The IAEA safety standards provide guidance in establishing the necessary radiation protection requirements and practices. These standards take into account the guidelines of the International Commission on Radiological Protection, and they incorporate the latest knowledge on the consequences of radiation exposure as presented in the United Nations Scientific Committee on the Effects of Atomic Radiation. This section covers the protection of people from harmful effects of radiation. Environmental protection is covered in Section 3.13.

3.8.1. Radiation protection: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

The NEPIO should develop an understanding of the additional hazards presented by operating an NPP over and above those posed by existing medical, industrial and research applications of ionizing radiation. In its report at the end of Phase 1, the NEPIO should identify how existing programmes will need to be enhanced to address operation of the NPP, transport and storage of nuclear material and management of radioactive waste.

Elements of the radiation protection infrastructure that need to be considered include the following:

— Resources available in the country for education and training of qualified experts, radiation protection officers and radiation protection workers;
— Radiation protection services in the country (e.g. personal dosimetry, environmental monitoring measurement equipment, calibration);
— Registers and inventories relating to doses from occupational exposure, events, radioactive waste, and shutdown and decommissioning (or closure) of facilities;
— Policies and strategies for management of radioactive waste arising from NPP operation (see Issue 17).

3.8.2. Radiation protection: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

Although there is no potential of radiation risk associated with the NPP operation until Phase 3, plans need to be prepared and preliminary actions taken in Phase 2 to develop infrastructure and programmes for radiation protection. These include the following:

— Amending or developing regulations by the regulatory body;
— Establishing or approving appropriate radiation dose limits for workers and the public, both for normal operation and for potential accidental exposures, by the regulatory body;
— Establishing a radiological environmental monitoring programme by the operating organization;
— Reflecting radiation protection provisions in the plant's design requirements;
— Planning for associated staff recruitment and training and the procurement of equipment and services.

3.8.3. Radiation protection: Phase 3 — Activities to implement the first nuclear power plant

The necessary radiation monitoring and protection infrastructure should be implemented before the first fuel arrives on the site and gives rise to radiation risks. By the time of the initial fuel delivery, the owner/operator should have in place the following:

— Radiation protection programme;
— Qualified and certified radiation protection officers;
— Radiation monitoring equipment on-site;
— Radiation dosimetry requirements for all workers;
— Programmes to minimize radiation exposure during plant operation and maintenance;
— Facility level and national arrangements for a dosimetry system.

The regulatory body should have reviewed the owner/operator's radiation protection programmes and verified their compliance with regulatory requirements, including environmental protection and requirements for procedures and equipment to protect workers and responders during accidents.

3.9. ELECTRICAL GRID

Nuclear power plants are most efficiently and safely run as base load generation, and the electricity demand should be large enough to make that possible. In addition, the frequency of the electrical grid system is difficult to control if more than 10% of the grid's capacity is suddenly taken off-line, as might happen if there were a reactor trip in a reactor unit with power output larger than 10% of the grid size. As a result, if a new nuclear reactor were to account for more than 10% of the total grid capacity at the time it was connected, detailed studies would need to establish that the system frequency could be reliably controlled in case of a reactor trip. In addition to its size, the grid's reliability is also important, since the off-site power it provides for safety systems at the NPP needs to be highly reliable.

Nuclear power plants can also provide heat to nearby facilities or, in certain situations (particularly for SMRs), they may provide electricity to a specific facility or local area. The interdependence between the grid and the NPP may be different for some SMR designs but, under this infrastructure issue, countries will need to consider the adequacy of the infrastructure to export energy and to

provide supplies required by the NPP. The rest of this text assumes that the NPP is connected to a national or regional grid for both export and import of electricity.

3.9.1. Electrical grid: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

An early step in considering the introduction of nuclear power is an assessment of the electrical grid's current and planned size and its reliability. For this reason, the grid operator should be represented in the NEPIO. The NEPIO Phase 1 study should address the following in connection with the electrical grid:

— The capabilities of the existing grid in relation to the NPP technology being considered, including its ability to reliably take an NPP's base load output, its ability to withstand a loss of the plant's output and its ability to reliably supply off-site power during outages and in an emergency;
— The anticipated future growth of grid capacity;
— The adequacy of frequency and voltage regulation and control;
— The historical reliability of the electrical grid;
— The need for reactive power to stabilize the grid;
— The likely scale of grid enhancements necessary for the sites under consideration;
— The potential for local or regional interconnections to improve grid characteristics.

3.9.2. Electrical grid: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

In Phase 2, the grid operator should identify the requirements for connecting an NPP. The grid operator, in cooperation with the owner/operator should undertake detailed studies to determine any expansion, upgrade or improvement necessary to accommodate the size, technology and site requirements that are anticipated for the new plant.

The grid operator, again in cooperation with the owner/operator, should have the following in place by the end of Phase 2:

— Plans for enhancing or expanding the grid to meet the needs of the new NPP, including the need for redundancy of lines for evacuation of electricity produced and supply of off-site power during outages and in an emergency;
— Plans to increase or strengthen regional interconnections to achieve acceptable grid reliability;

— Funding and/or financing to ensure that these plans are implemented on schedules compatible with the new NPP.

3.9.3. Electrical grid: Phase 3 — Activities to implement the first nuclear power plant

The execution of the plans adopted in Section 3.9.2 should create the necessary conditions to successfully commission and operate an NPP. During Phase 3, the grid operator, in conjunction with the owner/operator should carry out the following steps:

— Develop arrangements to ensure coordination of grid operations with the NPP operations.
— Verify the completion of all upgrades and enhancements to the grid and interconnections.
— Continue to analyse and improve the reliability of the grid.
— Ensure the ability of the grid to be restarted quickly in the event of grid collapse following trip of the NPP.

The owner/operator and regulatory body should ensure that there is a contingency plan for timely restoration of off-site power in the event of a major loss of grid capability.

3.10. HUMAN RESOURCE DEVELOPMENT

The knowledge and skills necessary to introduce nuclear power include much of the knowledge and skills needed for other large power plants. They include management and administrative skills and technical skills spread across most scientific and engineering disciplines. There are also specific needs for nuclear power, for example expertise in reactor and nuclear physics and nuclear materials science. This applies to the regulatory body, the owner/operator, TSOs and other relevant organizations.

In addition to their fundamental scientific and technical education, staff typically require special training in safety, security and radiation protection. A nuclear power programme requires all individuals to recognize that safety, security and safeguards are intrinsic to every aspect of the programme, to accept personal responsibility for these issues and to perform all their activities with that responsibility in mind.

Human resource needs will depend on the scope of the nuclear power programme, for example the number and variety of envisioned facilities and

technologies. How those needs are filled, both initially and in the longer term, will depend on the balance the country chooses between engaging foreign expertise and building up its own expertise, and how quickly it plans to shift that balance over time. Building up national capabilities will require significant education and training, and arrangements to gain practical experience. This can be achieved in a variety of ways, for example by hiring experienced foreign staff to work alongside national personnel and by secondment of national personnel to work in organizations abroad.

Certain roles will require several years of specialized training and experience in the design and operation of the specific technology chosen for deployment. Specialized education and training can be obtained from the suppliers of the NPP. To ensure a sustainable workforce, it is important for a country to expand its own education and training capabilities and to develop a strategy to retain skilled human resources.

3.10.1. Human resource development: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

At the beginning of Phase 1, the NEPIO's first human resource concern will be acquiring the competences required for conducting the Phase 1 activities. Many of the NEPIO's capabilities may come from staff within government agencies or other organizations, and the NEPIO should have the authority to enlist their participation as necessary. This could be achieved through secondment or through some other arrangement. Consultants and other experts should be used as necessary where domestic expertise is unavailable. However, the leadership should remain with national authorities, and the NEPIO should be capable of evaluating work performed by consultants and technical support service providers.

Important areas for consideration by the NEPIO in Phase 1 include the following:

— Identifying the full range of scientific, technical, managerial and administrative disciplines that will be needed to support the nuclear power programme.
— Surveying the national workforce to determine the availability of the required competences and identify competency gaps that might present a risk to the programme. There is also a need to consider the availability and mobility of such resources.
— Assessing the domestic and foreign capacity for educating and training the people who will be needed.

— Identifying specialized recruiting and training that will be needed in, for example, nuclear safety, nuclear security, safeguards, radiation protection and EPR.
— Considering how experienced, supervisory and managerial staff will be recruited and developed to support key organizations.
— Aligning recommendations on human resource development with recommendations about the country's policy on industrial involvement (see Section 3.18).
— Conducting a sensitivity analysis, as required, to consider potential changes in the programme scope or schedule, and the respective impacts on workforce planning.

The comprehensive report at the end of Phase 1 should include a review of human resource development options and recommend an outline of the principal features of a national human resource development strategy. These should include the following:

— Plans to develop the human resources needed for the nuclear power programme using national resources, supplemented as required by experienced staff from abroad and/or a strategic partnership with an experienced organization;
— Identification of needed enhancements to the national education and training infrastructure;
— An assessment of current capabilities in areas such as legal, financing, human resources and contracting;
— The need for recruiting experienced staff or consultants;
— The potential use of non-national support organizations;
— Plans for gaining international experience, both by secondment of national staff and recruitment of international expertise;
— Recruitment, remuneration and retention strategies to enable the above activities.

3.10.2. Human resource development: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

Early in Phase 2, the owner/operator and the regulatory body for nuclear power will be established. The intended senior staff should be in place or identified as soon as possible during Phase 2. Each of these organizations will need to develop its own human resources management strategy, including the respective workforce plans and associated priorities. While the national human

resources management strategy examines workforce needs at a high level, the human resources management strategies for these organizations include job specific requirements for education and experience, define training requirements, and establish strategies for recruiting and onboarding candidates.

The owner/operator should develop sufficient knowledgeable staff during Phase 2 to develop contract specifications / bid requirements and prepare for negotiating the contract. While operation and maintenance staff will not be in place in Phase 2, some knowledge of operational and maintenance requirements will be needed. Towards the end of Phase 2 and the beginning of Phase 3, the owner/operator needs to develop competences to be able to oversee the EPC contract. These activities require project management skills in addition to technical competences. The detailed planning for operations will happen early in Phase 3, in collaboration with the chosen vendor. However, some of the senior and specialist posts that the owner/operator will need in Phase 3 and beyond will require long periods of training and experience and such staff will need to be recruited in Phase 2.

The regulatory body will need to have much of its required competence available in Phase 2 to be able to establish the licensing process and issue the necessary regulations at the appropriate time. Early in Phase 3, it needs to have the competence to review a licence application and to oversee the manufacture of components and the construction of the NPP during Phase 3, and should develop workforce plans to meet those requirements.

The regulatory body may have agreements with other regulatory bodies or TSOs to provide specialized expertise to assist in the development of regulations and review of the licence application and safety report for the first plant(s). In view of the high value placed on licensing and inspection experience, the regulatory body should investigate opportunities for its own staff to gain experience through cooperative arrangements with foreign regulatory bodies or TSOs. Arrangements with those bodies experienced in regulating the reactor technologies that the country will most likely acquire would be particularly valuable.

Since the oversight of manufacturing and construction is a specialized and temporary task, the regulatory body may also consider the use of external resources to support this need. The above support arrangements will clearly impact the staffing requirements of the regulatory body and need to be reflected in the workforce plan.

In Phase 2, the NEPIO should establish a policy on national participation in the manufacture, construction, operation and support of the NPP, including the potential establishment of a national TSO. It should also develop a plan to put that policy into effect. The NEPIO should also ensure that the plans for enhancements to the national education and training infrastructure are implemented.

The NEPIO should oversee each organization's implementation of its plans, including the owner/operator, regulatory body, and research organizations and TSOs. The plans should cover education, training and experience requirements, and should consider bilateral and international training activities. The NEPIO should also look for opportunities to optimize development of training provision through sharing among the different organizations.

Depending on the country's acquisition strategy, human resource needs in Phase 2 may include the following:

— Engineering, operational, legal, financial, contracting and procurement expertise to prepare for contract and financing negotiations;
— Technical and scientific expertise needed to manage, conduct and review the site activities;
— Technical and regulatory expertise to develop and implement regulations, codes and standards for nuclear safety, site approval, plant licensing, radiation protection, safeguards, nuclear security, EPR, spent fuel and radioactive waste management, and decommissioning;
— Expertise on stakeholder engagement;
— Business and technical expertise for fuel cycle procurement and management.

3.10.3. Human resource development: Phase 3 — Activities to implement the first nuclear power plant

As noted in 3.10.2, towards the end of Phase 2 and the beginning of Phase 3, the owner/operator will need to recruit additional staff to oversee construction.

Early in Phase 3, the owner/operator will need to further develop and implement its workforce plan and the wider human resources management strategy on the basis of the technology selected, the staffing model proposed by the vendor and the knowledge gained during the negotiating process. The plan will need to take into account the following factors:

— Time needed to train personnel;
— The need to recruit staff early so that they can gain knowledge during construction and commissioning;
— The need to second people to other organizations to gain experience;
— Extent of training being provided by the vendor;
— Qualification of staff that requires a licence by the regulatory body;
— Extent and duration of secondments from experienced owner/operators;
— Loss of recruits to other relevant industries or other nuclear organizations;
— Development of capabilities for future projects;
— Approaches for obtaining technical support.

Specific human resource requirements include the following:

— Technical and scientific expertise needed to prepare a licence application, including the required safety analysis report;
— Technical and management expertise on construction project management and the management system required to control and supervise the plant's construction and commissioning;
— Full competent staffing for NPP operation, maintenance and technical support.

In addition, the owner/operator will need to establish an effective training system, including the operation of a full scope simulator, to support operation of the NPP. The full scope simulator should be constructed, commissioned and operational at least 18 months prior to loading of the fuel in order to train and qualify control room operators and other relevant staff.

The provision of the main elements of the training system for the owner/operator is typically included within the scope of the NPP vendor's services. The vendor will then be responsible for providing the training system infrastructure, necessary documentation and full scope simulator, together with delivering the training to support the qualification of the NPP operational staff. Regulatory requirements regarding the qualification and licensing of certain staff will also have an impact on the overall training and qualification arrangements. Other NPP staff will also require training, and the owner/operator will be responsible for developing and implementing their training programmes.

The regulatory body will need to have a training plan to support the development of competences for both the construction and the operational phases as its responsibilities shift from licensing and overseeing construction to overseeing operation. The strategy for this will depend on the number and timing of future units and will include the required training programmes on operational safety.

Its specific human resource requirements include the following:

— The technical and regulatory expertise to develop regulations and oversee compliance with industrial codes and standards;
— Full and competent staffing for the regulatory body, covering all aspects of authorization, inspection and enforcement.

Both organizations — the owner/operator and the regulatory body — will need to address workforce succession and personnel development planning to sustain competence in all areas of the national nuclear power programme.

The NEPIO needs to monitor the enhancements to the existing educational and vocational infrastructure to ensure that they are progressing satisfactorily to meet the evolving needs of the programme.

The NEPIO needs to monitor staff recruitment and retention across all organizations to ensure that the remuneration structures attract the required competence, enable the recruitment of international experience where required, and ensure comparable benefits among key organizations, particularly the regulatory body and the owner/operator. It is also important to monitor the success of the different mechanisms put in place to retain staff.

Depending on the country policy regarding a national TSO, consideration will need to be given to the development and funding of a research and development programme in selected areas.

All organizations involved in the nuclear power programme should have a systematic way of categorizing, disseminating and retaining knowledge, including training materials, obtained through international cooperation and contracted commercial services. The start of operation may involve significant support from an existing nuclear power country with plans to transfer knowledge. It is important that the plans for that knowledge transfer be clearly defined and resourced to ensure a smooth transfer of capability and responsibility.

3.11. STAKEHOLDER ENGAGEMENT

Strong, continuing stakeholder support is necessary through all phases of a nuclear power programme. Government policy is influenced by stakeholder confidence, which is in turn facilitated by effective stakeholder engagement. Effective engagement provides stakeholders with opportunities to express their views, addresses issues and concerns early, provides information on the nuclear power programme's rationale, plans and progress, and builds trust between stakeholders and decision makers.

Stakeholders include the general public, legislators, government agencies and decision makers, and, as the nuclear power programme progresses, the owner/operator, the regulatory body, suppliers, workers, communities near proposed sites, neighbouring countries and non-governmental organizations. A useful distinction can be made between 'statutory' and 'non-statutory' stakeholders — those that are required by law to be involved in any planning, development or operational activity, and those that do not have a formal role but may be directly or indirectly impacted, respectively.

Stakeholder engagement in a new nuclear power programme is best achieved through an open dialogue between the stakeholders and the entities that lead the programme, including the government, the owner/operator and

the regulatory body. The most influential stakeholders and societal opinion leaders will vary across countries and could include national and local government officials, heads of business and industry, the media, and leaders of non-governmental organizations. However, all concerned citizens should be provided with the relevant information and opportunities to be involved.

While open information programmes are important, sustained, successful sociopolitical involvement will depend on the competence and credibility of the organizations and individuals responsible for the nuclear power programme. The establishment of trust in the regulatory body and the owner/operator is vital to maintaining public confidence, and both organizations will need their own stakeholder engagement strategy and plan.

3.11.1. Stakeholder engagement: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

In Phase 1, it is important that the government and the NEPIO understand the importance of gaining and keeping the confidence of the country and the international community by maintaining open and timely interactions regarding all aspects of the nuclear power programme. The government and the NEPIO should address this commitment from the very beginning.

Nuclear communication is a specialized field that should be placed in the hands of trained communications experts, working in consultation with technical experts. Communication with interested parties should be properly managed in order that nuclear professionals maintain the trust of political authorities and the public.

During Phase 1, the NEPIO should take the following initial steps:

— Conduct surveys to determine the public's knowledge and receptiveness to nuclear power.
— Develop public information tools that respond to the results of the surveys and explain the government's interest in, and the potential benefits from, nuclear power.
— Develop and begin implementing a plan of interaction with all stakeholders, including neighbouring countries[9].
— Train senior staff to interact with stakeholders in response to any request.

[9] States party to conventions or agreements such as the Convention on Nuclear Safety and the United Nations Economic Commission for Europe (UNECE) Convention on Environmental Impact Assessment in a Transboundary Context have obligations regarding foreign stakeholders.

The NEPIO's comprehensive Phase 1 report should take account of the views of stakeholders involved in the Phase 1 process and propose a stakeholder engagement plan identifying the role of each of the three key organizations, based on transparency and openness. This plan should identify and prioritize the stakeholder groups to be considered, identify the issues and means of engagement that are considered most important for each stakeholder group, and identify the tools and approaches that will be used.

3.11.2. Stakeholder engagement: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

As the country begins to implement the plan recommended in the Phase 1 report, the three key organizations should establish stakeholder engagement programmes. Different organizations will have different messages, mechanisms and principal stakeholders, and the NEPIO should provide a continuing forum for communication and cooperation among the key parties and ensure clarity about the roles and responsibilities of each organization in stakeholder engagement.

The government should continue public information and consultation activities according to the plan developed in Phase 1.

Appropriate actions in Phase 2 are the following:

— The government continues to communicate the reasons for, and expected benefits of, nuclear power and to respond to concerns raised by stakeholders.
— The government communicates the national process used for site selection, supporting the owner/operator, who should engage local stakeholders and address their issues.
— The regulatory body explains its independent role in licensing, inspection and compliance.
— The regulatory body establishes and communicates the formal process for public participation in licensing.
— The owner/operator explains the basic technology being employed, its construction plans, its safety responsibilities and the impact on, and benefits for, the local community.
— All organizations conduct knowledge and opinion surveys as part of their stakeholder engagement programmes.
— All organizations ensure that senior staff who communicate with the public are trained.
— All organizations openly discuss issues and how they are being addressed.
— Public information centres are established as appropriate.

3.11.3. Stakeholder engagement: Phase 3 — Activities to implement the first nuclear power plant

By the start of construction of the NPP, each of the organizations involved should have established trust and credibility with all stakeholders. The communication efforts should continue throughout the construction and preparation for operation, and the NEPIO should continue to provide a forum for communication and cooperation among the key parties.

Following are the appropriate actions in Phase 3:

— All organizations continue to conduct surveys as part of their stakeholder engagement programmes.
— The government continues to communicate the reasons for, and expected benefits of, nuclear power and respond to concerns raised by stakeholders.
— The owner/operator routinely communicates the construction progress and preparations for operation.
— The regulatory body continues to communicate its role and provides information on its licensing, inspection and enforcement programmes.
— The regulatory body provides opportunities for public involvement in licensing, inspection and enforcement according to the process established in Phase 2.
— Governmental agencies (e.g. for environmental protection, emergencies and public and occupational health) communicate on issues relevant to their responsibilities.
— The regulatory body and owner/operator establish plans for routine communication, once the NPP is operational, with all stakeholders, including local communities.
— The government, regulatory body and owner/operator communicate the on-site and off-site emergency response plans.
— All organizations continue to openly discuss issues and how they are being addressed.

3.12. SITE AND SUPPORTING FACILITIES

This issue considers not only the site of the NPP itself but also the additional facilities that will be required to support construction, such as ports, roads, services and housing for construction workers. In addition, sites for other facilities, such as interim spent fuel storage or other fuel cycle and waste processing facilities, should also be studied. The possibility of siting a low level

waste disposal facility near the new NPP should be considered, as it would reduce waste transport.

The project to select the site for an NPP needs to begin early, be well managed, and provide early, substantive and frequent communication with all stakeholders, including regulators.

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 in-house siting team have enough expertise to know what is required, what risks are associated with unknown or developing information, and how the collected information is used for decision making.

Siting studies involve several stages comprising identifying suitable areas, ranking specific sites and justifying the suitability of chosen sites. To ensure that each stage builds smoothly on its predecessor, it is essential to maintain a validated, referenced databank with all information collected on all the sites that are considered. Good data management is important not just for selecting and licensing the best site, but also to help to resolve possible future issues that arise during operations and require further justification. It also facilitates future siting studies for future NPPs.

In some Member States, activities for selection and/or evaluation of a site for an NPP were launched and performed many years ago but, for various reasons, the nuclear power projects did not continue. Since that time there have been improvements in international practice for data collection and analysis, and regulatory requirements and guidelines may have substantially changed. In such situations it will be necessary to conduct a comprehensive assessment of past studies and to formulate and implement a work plan for completing and updating all related data and information, based on a gap analysis between existing data and current practice.

The selection and evaluation of a suitable site for an NPP requires the adoption and application of a clear set of attributes and associated criteria. This generally involves exclusionary attributes, used to discard regions/areas/sites that are unacceptable where there are no practicable engineering solutions, and discretionary attributes, used to identify favourable areas and ultimately to rank potential sites where protective engineering solutions are available. For discretionary attributes, and the siting decisions relate to cost, schedule and risk. For example, a higher water table increases construction costs and flooding risks, while ease of access to cooling water reduces operating costs.

Attributes, whether exclusionary or discretionary, can be grouped into four types of factors, as described below:

— Health, safety and nuclear security factors (e.g. natural or human induced external events, characteristics related to radiological impact);
— Engineering and cost considerations (e.g. cooling water, transport, electrical grid);
— Socioeconomic considerations (e.g. land use planning and restrictions, impact on local economy);
— Environmental considerations (addressed in Section 3.13).

As part of their siting studies, each country will need to develop its own comprehensive set of criteria. These will include criteria related to the following:

— Ease of integration into the electric system;
— Demography;
— Land use, including environmentally or culturally sensitive land;
— Geology and tectonics;
— Seismology and volcanology;
— Other external natural hazards;
— Heat removal options;
— Hydrology;
— Meteorology;
— Oceanography;
— Nuclear safety and radiation protection;
— Nuclear security;
— Environmental impacts and environmental monitoring;
— Risks from human induced events;
— Availability of local infrastructure;
— Ease of access;
— Legal constraints;
— Public interaction;
— Emergency planning.

3.12.1. Site and supporting facilities: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

Siting activities need to begin early. In Phase 1, these will be the responsibility of the NEPIO. In the site survey stage, large regions of interest are investigated using defined criteria (mainly exclusionary) to find potential suitable areas. At this stage, if large areas that are essentially similar in characteristics can

be identified, then flexibility is maintained to select sites later on the basis of other characteristics or perhaps the strategic interests of the Member State. If potential areas are quite constrained, then perhaps only specific sites of minimally adequate area for the project can be identified at this stage.

The site survey should include consultations with stakeholders early in the process and before any substantive decisions are made. Local public acceptance can be a key parameter in selecting a site. The site survey should identify one or more candidate sites for the NEPIO to recommend in its comprehensive report at the end of Phase 1. If acceptable candidate sites cannot be identified, the programme cannot go forward.

3.12.2. Site and supporting facilities: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

The second stage of the siting process is site selection, in which the suitable candidate sites identified previously are ranked by comparing them on the basis of discretionary criteria. The selection of more than one site is advisable to provide more than one option in case further information collected during detailed site characterization identifies the site to be unsuitable.

The third stage of the siting process is site characterization. This stage includes the detailed assessment of the selected site or sites to demonstrate site suitability; perform detailed characterization, including an environmental assessment (see Section 3.13); and derive the site specific design parameters for the NPP. These should be reflected in the bid invitation specifications for the NPP. This stage will also involve initiating environmental monitoring to establish environmental characteristics and an environmental baseline. If the selected site is close to the border of the country, there may be a need for additional activities to inform and cooperate with neighbouring countries.

Early in Phase 2, the regulatory body will need to define siting requirements that should be taken into account by the owner/operator in the final site selection and characterization.

In this phase, there should be open and transparent engagement with key stakeholders, including decision makers, the public, media and neighbouring countries. Activities may include organizing and supporting a public information office or information centre, strengthening communication channels with local and regional elected officials and conducting meetings or workshops with interested parties.

During Phase 2 it is also necessary to develop implementation plans for necessary improvements to local infrastructure at the preferred site or sites, such as access, services and facilities.

3.12.3. Site and supporting facilities: Phase 3 — Activities to implement the first nuclear power plant

Phase 3 includes the formal confirmation of the site related design bases and the completion of all licensing and approval processes established by the nuclear regulatory body. It includes ongoing monitoring of the site before operation to confirm its acceptability. Monitoring will continue subsequently to confirm that the site continues to meet the design objectives.

3.13. ENVIRONMENTAL PROTECTION

Mitigation of climate change is one of the drivers for introducing nuclear power, but with that comes the need to protect the environment from any harm that might arise from the use of nuclear power.

Protection of the environment from harmful effects of ionizing radiation is a fundamental safety objective. IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards,[10] further states:

> "Protection of the environment includes the protection and conservation of: non-human species, both animal and plant, and their biodiversity; environmental goods and services, such as the production of food and feed; resources used in agriculture, forestry, fisheries and tourism; amenities used in spiritual, cultural and recreational activities; media, such as soil, water and air; and natural processes, such as carbon, nitrogen and water cycles."

Many countries that are considering embarking on or expanding a nuclear power programme have existing legislation that subjects major projects, both nuclear and non-nuclear, to environmental restrictions and obliges the organizations responsible to conduct an EIA to inform the governmental planning and decision making process. For an NPP, the EIA will be broad in scope and the radiological EIA is only part of the overall EIA. The control of non-radiological aspects of health, safety and the environment also need to be considered although the IAEA safety standards do not specifically address these aspects.

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[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014), https://doi.org/10.61092/iaea.u2pu-60vm

3.13.1. Environmental protection: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

During Phase 1, the government may consider conducting a strategic environmental assessment (SEA) to support the understanding of potentially significant negative as well as positive environmental implications of a nuclear power programme, to identify different development options and mitigation measures, and to assess their environmental impacts from the outset of the formulation of policies, plans and programmes. This SEA may build upon any prior environmental assessments conducted to support the development of the national energy policy and will inform future project specific assessments and decisions, for example during the stages of the authorization process.

The NEPIO should review the suitability of the country's existing framework for environmental protection and its international obligations, and it should collect and analyse initial environmental information in connection with the site survey described in Section 3.12. If an SEA is conducted, the NEPIO's comprehensive report at the end of Phase 1 should reflect its findings. It should also include recommendations about possible enhancements or clarifications in existing environmental laws, regulations and responsibilities and plans for further public consultations.

3.13.2. Environmental protection: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

Based on the recommendations from Phase 1, any desired enhancements or clarifications in existing environmental laws, regulations and responsibilities should be implemented in Phase 2.

The country's environmental regulatory body should develop the skills and resources required to fulfil its responsibilities, and the interface between it and the nuclear regulatory body should be clearly established.

A project specific EIA should be completed in Phase 2 for the preferred or candidate sites, according to the country's environmental laws and regulations. The conduct of an EIA is a multistep process involving various statutory and non-statutory stakeholders. Depending on the laws and practices of the country, the EIA may be led by the environmental regulatory authority or by the nuclear regulatory body acting as the competent authority. In either case, the environmental authority and the nuclear regulatory body should coordinate their activities and decision making processes, for example through a memorandum of understanding. The owner/operator in many countries is also required to gather environmental baseline data as part of this process.

Important issues to be considered include the following:

— Pathways for effluent releases, environmental transport and concentration in media in the surrounding environment;
— External and internal radiation exposure pathways to humans;
— Predominant plant and animal life and their particular sensitivities;
— Local population demographics and trends;
— Cultural heritage preservation (people and land);
— Predominant land use;
— Data relating to water use and the possible need for cooling towers;
— Sites and means for disposal of hazardous waste;
— Impacts of construction activities on the local environment.

The EIA should be submitted to the appropriate authority. The authority should review and assess the EIA for the site selected with the involvement of the relevant shareholders, the public and neighbouring countries on the basis of the policy and legislation of the country.

Based on such assessments, the bid invitation specifications developed in Phase 2 should include a comprehensive specification of the environmental site conditions, factors, characteristics and data for the sites.

3.13.3. Environmental protection: Phase 3 — Activities to implement the first nuclear power plant

In Phase 3, the owner/operator will complete all licensing and approval processes established by the nuclear regulatory body and the environmental regulatory body for the nuclear power programme. The licensing conditions for facility operation should include any specific environmental requirements identified in the environmental studies and assessments carried out in Phases 1 and 2.

In Phase 3, the operator should implement an environmental monitoring programme, including a radiological environmental programme, in line with regulatory requirements. The purpose of the environmental monitoring programme is to ensure that the environmental impacts during construction and operation stay within assessed and accepted limits and, in case they do not, to initiate a process to address the activity causing the observed exceedance values.

Environmental limits and conditions, for example radiological (including the initial consideration of radioactive environmental discharges limits) and non-radiological, should be defined and regulatory oversight/monitoring process should be in place to ensure that they are met.

3.14. EMERGENCY PREPAREDNESS AND RESPONSE

Despite the very low likelihood of a large release of radioactive material from an NPP, EPR is a necessary element for the protection of plant personnel, emergency workers and the public, as required by the fifth level of defence in depth. This level of defence in depth is valid for SMRs as well, calling for adequate EPR arrangements to be in place. Emergency preparedness ensures the capability to take actions that will effectively mitigate the consequences of an emergency.

The establishment of an effective EPR framework usually involves various organizations at different levels of government, some of which may form part of the existing civil protection network and crisis management organizations, as well as the regulatory body and the owner/operator of the NPP. Ultimately the government is expected to clearly specify, through the legal framework, the roles and responsibilities of the various entities and the means of coordination and decision making. In the legislation, there should be provisions for effective coordination of and communication between the owner/operator and emergency response organizations.

3.14.1. Emergency preparedness and response: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

The NEPIO should develop an understanding of the requirements for EPR. Its comprehensive report at the end of Phase 1 should evaluate the status of the country's EPR arrangements and ensure that the government is aware of the following:

— Any expansion of EPR arrangements that will be required to support a nuclear power programme;
— The resources that will be needed to develop, maintain and demonstrate an emergency response capability;
— Its responsibility for EPR and the need to define clear responsibilities for all organizations involved.

The evaluation should address any need for new arrangements at an international level, including participation in international legal instruments and cooperation with neighbouring countries, the IAEA and other international organizations. The Phase 1 site survey discussed in Section 3.12.1 should cover site characteristics important for EPR.

3.14.2. Emergency preparedness and response: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

In Phase 2, the evaluation and recommendations in the comprehensive report about the country's EPR status and needs should be used as the basis for enhancing EPR capabilities. During Phase 2 the following should be achieved:

— The government should specify the response organizations at national, regional and local levels with responsibilities for EPR and establish a national coordination mechanism.
— The regulatory body should specify the general framework for EPR. This should be based on a large spectrum of emergency scenarios and associated consequences, for which a probabilistic approach may be used to complement the deterministic approach. Considering emergency scenarios that include nuclear security events as triggering events will help the regulatory body establish regulations addressing all EPR requirements.
— Gaps in existing national and local institutions and communication networks should be identified and filled or included in an action plan to be implemented in Phase 3.
— The regulatory body and, as appropriate, other competent authorities should start developing the regulations on EPR.

3.14.3. Emergency preparedness and response: Phase 3 — Activities to implement the first nuclear power plant

During Phase 3, before the first nuclear fuel arrives on site, emergency arrangements should be completed and tested. As far as possible, the interfaces between emergency arrangements and security should be considered to ensure an optimized mitigation strategy throughout the NPP operations.

The government should make provisions to ensure that roles and responsibilities for preparedness and response for a nuclear or radiological emergency are clearly specified and clearly assigned. Consistent with these arrangements, the following should be completed:

— The regulatory body and, as appropriate, other competent authorities should establish detailed regulations on EPR.
— The owner/operator should develop and implement emergency arrangements for the NPP to support preparedness for an effective on-site response.
— The government, the regulatory body and other response organizations should develop and implement emergency arrangements to support

preparedness for an effective off-site response at the local and national levels and, as appropriate, international cooperation.

— The government and the regulatory body should ensure that the emergency plan of the NPP is coordinated with the plans of the relevant response organizations that would be involved in emergency response.
— The regulatory body should review and assess the on-site emergency arrangements for NPPs and verify the compliance of the on-site emergency arrangements with regulatory requirements.
— The government, the regulatory body, other response organizations and the owner/operator should demonstrate their emergency response capabilities by conducting exercises including local authorities and communities and the media.
— The regulatory body, operating organization and other response organizations should conduct a programme of regular training, drills and exercises to test the established arrangements.

3.15. NUCLEAR SECURITY

Nuclear security concerns the prevention and detection of, and response to, theft, sabotage, or other malicious acts related to nuclear material, other radioactive material and associated facilities and activities.

The responsibility for nuclear security rests entirely with the country. Its nuclear security regime comprises its legal and regulatory frameworks and administrative measures governing nuclear security, the organizations responsible for nuclear security, and the nuclear security measures themselves. Because of the increase in the use of digital equipment in the nuclear industry, the legal and regulatory frameworks should also consider computer security so that a compromise of digital systems does not contribute to a nuclear safety or security event. The nuclear security regime is part of the country's overall security regime.

The State's nuclear security policy and strategy should achieve the following:

— Identify the State's international obligations and relationships with key international institutions in relation to nuclear security.
— Take into account good practices in nuclear security as set out in relevant guidance documents.
— Implement a comprehensive nuclear security infrastructure.
— Assign responsibilities to the institutions within the State that will establish, maintain, evaluate and sustain the nuclear security infrastructure.

— Identify measures to effectively sustain, and to continuously improve, the nuclear security infrastructure through knowledge management, succession management and capacity building.
— Identify an appropriate process to facilitate the sharing of information and to achieve the goals of combating offences related to nuclear security events including terrorist acts.
— Identify nuclear security measures for response to nuclear security events based on the national threat assessment or design basis threat.
— Identify measures for prosecuting and/or extraditing alleged offenders for offences related to nuclear security events.

For its nuclear security regime to be effective, all organizations assigned responsibilities for nuclear security — which may include the national security and intelligence authorities, the nuclear regulatory body, customs and border protection, and licensed facility operators — need to be fully aware of the importance of nuclear security and ensure the development of a nuclear security culture.

Appropriate interfaces should be developed and maintained between the security organizations and the authorities having responsibility for nuclear safety and safeguards to ensure coordination and mutual reinforcement of activities.

3.15.1. Nuclear security: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

The NEPIO's comprehensive Phase 1 report should prepare recommendations concerning the national policy and strategy for nuclear security and the roles and responsibilities of government agencies for nuclear security based on the national threat assessment. The report should cover the following:

— Identify all relevant international instruments related to nuclear security and set out plans for the State to become party to each.
— Identify all necessary elements of a domestic legal and regulatory framework for nuclear security and plan for implementing them through new or amended legislation.
— Evaluate the country's human resource needs and the necessary expertise to establish the legal and regulatory framework.

3.15.2. Nuclear security: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

During Phase 2, the following actions should be implemented:

- The legislative and regulatory frameworks for nuclear security should be put in place (see Sections 3.5.2 and 3.7.2).
- The government should ensure that each competent authority has the appropriate technical, financial and human resources to carry out its role and responsibilities and the authority to obtain appropriate expertise as needed.
- Nuclear security requirements for the physical protection of nuclear material and nuclear facilities should be defined through the development of design basis threat(s);
- Programmes for the management of sensitive information, promotion of a nuclear security culture and trustworthiness of personnel should be put in place.
- Roles and responsibilities should be assigned for preparing for, detecting and responding to nuclear security events.
- A programme should be put in place to develop competences to approve nuclear security plans and to inspect facilities to verify the plans' effectiveness.

3.15.3. Nuclear security: Phase 3 — Activities to implement the first nuclear power plant

During Phase 3, the competent authorities should implement and fulfil the responsibilities defined in the legal and regulatory framework. Security arrangements will need to come progressively into place in order to secure the NPP site during construction and the fuel once it arrives on site. The required timing of activities should be agreed by the main organizations. The main actions to be completed in Phase 3 are:

- Construction, testing and acceptance of the physical protection system by the owner/operator as approved by the regulatory body;
- Ensuring good interface between safety, security and safeguards arrangements;
- Development of the security plan by the owner/operator;
- Approval of the security plan by the regulatory body;

— Expansion, as required, of programmes (developed in Phase 2) for the management of sensitive information, promotion of a nuclear security culture and trustworthiness of personnel;
— Implementation of nuclear security requirements for protecting nuclear material and facilities, and the inspections, verification and on-site exercises needed to demonstrate the physical protection system's effectiveness;
— Development and implementation of security arrangements for the transport of fresh nuclear fuel to the site;
— Implementation of the national response plan, including arrangements with outside response forces to supplement on-site response, as well as training and exercises.

3.16. NUCLEAR FUEL CYCLE

The fuel cycle has two components. The front end comprises activities prior to using the fuel in an NPP. The back end comprises activities after the fuel is removed from the reactor. The front end consists of mining, milling, chemical conversion, enrichment and fabrication. The back end consists of spent fuel storage, transport and either the disposal of spent fuel or the reprocessing and disposal of high level radioactive waste. Enrichment and reprocessing technologies are sensitive from the point of view of proliferation. A country should recognize that its consideration of fuel cycle strategy is closely related to the consideration of nuclear technology. It should also recognize the long term (more than 100 years) implications of its fuel cycle strategy.

All front end services can be routinely purchased from the international nuclear market, which reduces the need to develop a national fuel cycle infrastructure. Consideration needs to be given to the nature of such contracts, as it is possible to have multiple procurement contracts covering the specific steps of purchase of uranium ore, conversion, enrichment and fuel fabrication. Back end functions are generally provided nationally, and some can also be provided internationally. On-site and interim storage are generally the responsibility of the owner/operator. Technologies for spent fuel storage are mature, with multiple suppliers available to respond to specific needs. Ultimate disposal is generally a national responsibility, either of the government or the owner/operator. There are also some opportunities for international reprocessing of spent fuel.

In-core fuel management is also a key aspect of the fuel cycle and this is a highly technical area using specialist computer codes. While the owner/operator remains responsible for efficient and safe fuel management, such services can be bought from vendors/fuel suppliers if a country does not wish to develop its own capability. It is important to recognize that such competence will take many years

of development and may benefit from collaboration with universities and fuel supplier organizations.

3.16.1. Nuclear fuel cycle: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

In Phase 1, the NEPIO should develop a broad knowledge of the steps in the nuclear fuel cycle and identify approaches that may be feasible for the country. Investments and human resource needs will vary considerably across options. For most countries, the development of a completely indigenous nuclear fuel cycle concurrent with the first NPP would be difficult and unlikely to yield economic benefits. However, a country with abundant uranium may decide to embark on mining and milling operations while purchasing conversion, enrichment and fabrication services.

In Phase 1, the NEPIO should also analyse the country's energy security concerns and options to address them, including the potential procurement options.

Regarding the back end, the vendor should be requested to provide facilities for on-site spent fuel storage for at least ten years of cooling time, irrespective of future plans for the fuel. It is also likely that interim spent fuel storage, whether on-site or off-site, will be needed for several decades. The NEPIO should analyse possible alternative options for spent fuel and radioactive waste management so that decisions taken at the end of Phase 1 are well informed about the challenges that spent fuel and waste create for a nuclear power programme. The issue of ultimate disposal is discussed in Section 3.17.

The above considerations should result in the development of a fuel cycle policy.

The NEPIO Phase 1 study should consider the following:

— The individual steps in the nuclear fuel cycle;
— Potential sources of supplies and services for each step;
— National natural resources and capabilities with respect to each step;
— Feasible options for a national fuel cycle strategy covering all steps in both the front and back ends;
— Security and non-proliferation implications of different fuel cycles;
— Human resource requirements.

On the basis of this analysis, the comprehensive report should identify realistic options for the front and back end, noting implications for national resource use, cost, energy security, nuclear security and non-proliferation issues.

3.16.2. Nuclear fuel cycle: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

Decisions on the fuel cycle strategy should be made in Phase 2, since the chosen strategy will influence the bid invitation specifications to be prepared in this phase. These need to cover the following:

— Arrangements for purchasing the first reactor core and the desired number of reloads;
— The specific fuel cycle services (such as in-core fuel management) that will be either purchased or developed domestically as part of the nuclear power programme;
— The long term strategy with respect to purchasing or developing fuel cycle capabilities;
— The long term strategy with respect to reprocessing;
— The capacity of the on-site spent fuel storage to be contracted along with the first NPP;
— The strategy for interim spent fuel storage, transport and ultimate disposal.

3.16.3. Nuclear fuel cycle: Phase 3 — Activities to implement the first nuclear power plant

During Phase 3, the fuel for the initial core will be delivered to the site, provisions for the additional fuel inventory, in accordance with the national strategy, will have been contractually committed and on-site spent fuel storage will have been constructed as part of the NPP.

Once fuel arrives on site, the site becomes a nuclear site and all arrangements to meet the licence requirements (e.g. radiation protection, safety, security, safeguards, and EPR) should be in place.

By the end of Phase 3, it will also be necessary to define timescales and responsibilities for implementing the interim storage strategy, including identifying a suitable location, storage capacity, transport capabilities, stakeholder engagement, provision of emergency response capability and funding arrangements. The plans for interim spent fuel storage will need to be consistent with the on-site storage capabilities. The regulatory body should also develop regulations covering spent fuel and radioactive waste.

3.17. RADIOACTIVE WASTE MANAGEMENT

Radioactive waste will be produced during the operation and decommissioning of the NPP. The management and disposal of all radioactive waste is an essential aspect of nuclear power. Such waste needs to be properly managed to avoid imposing undue burdens on future generations. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management stipulates that radioactive waste should be disposed of in the country in which it is generated. However, it also allows the possibility of waste being disposed of elsewhere in the interests of safety and efficiency.

Radioactive waste is divided into six levels, three of which require particular attention when developing the infrastructure for a nuclear power programme: low, intermediate and high.[11] The ability to manage low level waste (LLW) and intermediate level waste (ILW) exists in many countries in conjunction with medical, industrial and research applications. Programmes and technology for LLW and ILW minimization and processing have been implemented in many countries, and some countries also have operational disposal facilities for LLW and ILW. Even in these cases, however, a country introducing nuclear power will need to understand the additional volumes of waste produced during operation and decommissioning and the different spectrum of radioactive isotopes in LLW and ILW associated with nuclear power.

No disposal facility for high level waste (HLW) (including spent fuel declared as waste or radioactive waste produced mainly from reprocessing of spent fuel) is yet in operation. The most advanced projects are scheduled for operation in the near future. In the meantime, the demonstrated capability to store spent fuel safely for decades provides time for developing final disposal strategies. Nevertheless, waste disposal is often a subject of public concern, and early consideration should therefore be given to the country's final disposal strategy. Currently, the most common strategy for HLW is planned disposal in deep geological formations.

Planning for decommissioning begins at the design stage, seeking to minimize radioactive waste and its cost, and continues throughout the lifetime of the facility. It includes preparation of an initial decommissioning plan as part of the licence for construction of an NPP.

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[11] The other three levels are exempt waste, very short lived waste and very low level waste.

3.17.1. Radioactive waste management: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

In Phase 1, the NEPIO should identify the additional responsibilities for radioactive waste that will come with a nuclear power programme. It should communicate effectively about the options for safely and securely dealing with radioactive waste and should consider the following:

— The country's existing capabilities, regulatory framework and experience with radioactive waste handling, storage, transport and disposal;
— Additional volume of LLW and ILW, and the variety of isotopes expected from the operation and decommissioning of the NPP;
— Technological options and research on the ultimate disposal of spent fuel and HLW from reprocessing;
— Options for financing spent fuel and HLW management and disposal;
— The benefits of becoming a party to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management if the State is not yet a party;
— Human resource and other infrastructure development needs associated with radioactive waste management for a nuclear power programme.

On the basis of this analysis, the comprehensive report should identify the issues of radioactive waste management for an NPP and identify the proposed options for addressing them.

3.17.2. Radioactive waste management: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

During Phase 2, the following needs to be achieved:

— The government and other interested parties, as appropriate, should establish the national policy and strategy for radioactive waste management, spent fuel management and decommissioning, including timescales for site investigations for the purposes of radioactive waste disposal.
— The national planning for radioactive waste disposal should consider the extent to which geological conditions exist in the country to allow disposal of all types of radioactive waste and/or the potential for contracting for waste disposal with other countries.
— The government, together with the operating organization, should identify the requirements and timescales for enhancing the country's radioactive

waste disposal programmes and facilities to accommodate radioactive waste from operation of the first NPP. They should also consider the requirements and timescales to establish a national organization responsible for radioactive waste management or to extend the role of the existing organization for radioactive waste management if one already exists in the State.

— The regulatory body should establish the necessary regulatory requirements on radioactive waste management, spent fuel management and decommissioning, as necessary for bid specifications or contract negotiations.
— Plans should be established to fully finance long term radioactive waste management, radioactive waste disposal and decommissioning, as noted in Section 3.4.2.
— The owner/operator should develop, for inclusion in the bid invitation specifications, provisions for minimizing radioactive waste volumes and toxicity, requirements for processing and storage of radioactive waste that will be generated from the operation of the NPP and associated facilities, and requirements for a decommissioning plan.

3.17.3. Radioactive waste management: Phase 3 — Activities to implement the first nuclear power plant

LLW and ILW will be generated as soon as the reactor begins operation. Therefore, towards the end of Phase 3, the following should be fulfilled:

— Appropriate facilities for the storage or disposal of LLW and ILW should be fully operational and prepared to receive radioactive waste from the NPP.
— The owner/operator should prepare a programme for radioactive waste management (including liquid and gaseous radioactive effluents management) and spent fuel management and should prepare the corresponding chapters of the safety analysis report.
— The regulatory body should review and assess the radioactive waste management and spent fuel management programme.
— The responsible organization and funding system for the management of radioactive waste should be in place.
— An initial decommissioning plan should have been developed as part of the licensing of the NPP, and appropriate funding arrangements should be in place.

The organization leading the national planning for radioactive waste disposal should continue to follow international progress on HLW disposal, and national policy should be revised as appropriate.

3.18. INDUSTRIAL INVOLVEMENT

Several commodities, components and services are required to construct and support the operation of an NPP. Such supporting activities can be a source of jobs and economic growth for the country. They can also help to transfer technology to the country. However, supplying specialist equipment and services requires an industry that can comply with nuclear codes, standards and quality requirements. In the early stages of developing the country's nuclear power programme, the NEPIO should establish a policy on enhancing industrial capabilities based on a graded approach that identifies the quality standards required and recognizes the capability of national industries, the level of investment and the need for government support. As the programme proceeds, the policy should lead to plans and their eventual implementation to develop the desired level of industrial involvement[12].

3.18.1. Industrial involvement: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

The NEPIO Phase 1 study should assess opportunities for national and local industrial involvement in the nuclear power programme. Its Phase 1 report should identify the level of industrial involvement that could be achieved with current capabilities and should identify potential opportunities to increase the level of involvement with planning and investment. Any industrial involvement strategy needs to align with the procurement strategy for the NPP and recognize the role of the EPC contractor in selecting suppliers.

The study should identify the range of quality standards necessary to provide equipment and services, noting where they are more stringent than for other industrial operations. It should also identify any opportunities for joint ventures and partnerships with existing suppliers to assist in national industrial involvement. It is important that the NEPIO carry out a realistic assessment of the country's capabilities. A country's first NPP may be constructed with limited local industrial involvement, but there may well be plans to expand that involvement as the programme develops.

The NEPIO Phase 1 study should carry out the following tasks:

— Research (including discussions with potential vendors) opportunities for national involvement in the nuclear power programme;

[12] Another term for increasing national and local participation is 'localization'.

— Assess national and local industrial capabilities and their potential involvement, including the training and development needs to realize such a level of involvement;
— Assess industry's interest in participating in the nuclear power programme;
— Assess the level and likelihood of the investments required to upgrade industrial facilities and programmes;
— Recommend targets for short term and long term industrial participation and strategies to reach those targets.

3.18.2. Industrial involvement: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

On the basis of the short term and long term targets recommended in the comprehensive report, the government and industry should establish dialogues with potential vendors, identify industries committed to participating in the nuclear power programme and agree, as appropriate, on an action plan for upgrading capability.

The dialogue will need to recognize the requirement to supply on schedule, at competitive prices and with appropriate quality controls and assurance, commodities, components and services for building and operating an NPP. The results should be included in discussions related to early vendor selection or the bid invitation specifications and evaluation criteria developed during Phase 2, which may include incentives to encourage bids promoting domestic industrial involvement. Whatever the desired degree of national industrial participation may be, it is important that the actual level of involvement should be within the domestic industry's ability to meet schedule and quality requirements on time and within budget. Construction delays can greatly increase costs and decrease regulatory and public confidence.

Thus, in Phase 2, the owner/operator should consider the following:

— National or local suppliers who can reliably supply commodities, components or services to the nuclear related or non-nuclear portions of the NPP;
— Upgrades in skills and capabilities that are realistic in the given time frame and required to support nuclear construction.

Decisions should be made about using national or foreign sources for commodities, components and services, and these should be reflected in any negotiations or localization criteria in the bid invitation specifications developed in this phase.

3.18.3. Industrial involvement: Phase 3 — Activities to implement the first nuclear power plant

The government, in Phase 3, should continue to promote educational and industrial development for national participation in the nuclear programme. As the construction phase of the nuclear power programme nears completion, a reassessment of the supply sources to support operation can be undertaken. If the national and local industrial structure has progressed sufficiently, the supply of spare parts, consumable supplies, maintenance services and calibration services can be allocated accordingly. However, the same supplier qualification necessary for facility construction by the owner/operator is also needed for operational support, and in some cases the operational requirements may be even more stringent.

If the industrial involvement strategy includes increased involvement for future NPPs, it is important to review the progress in capability development and identify the lessons learned from the first project.

3.19. PROCUREMENT

Procurement considerations need to address all potential contracts. These may cover pre-project services (e.g. siting), preconstruction contracts (e.g. support for licensing), construction, fuel supply and associated services, and operational support.

This publication assumes that a country will procure its first NPP via a turnkey contract where the main contractor is responsible for managing subcontractors. However, even under a turnkey contract the owner/operator will need a significant procurement and engineering team, in order to fulfil the knowledgeable customer role in overseeing the contract implementation.

Procurement related activities may have an impact on safety. A graded approach in overseeing the contract implementation allows the owner/operator to focus on critical services and equipment and ensure that safety is not adversely affected.

Characteristics of a knowledgeable customer include the following:

— Knowledge of what is required, the role of the item or how a study will be used;
— Ability to properly specify the objectives, scope and requirements of the item/work;
— Ability to understand and apply the outcome of work;

— Ability to oversee the item/work in accordance with the owner's procedures and management system and to perform technical reviews of the work when necessary.

Although these characteristics also apply to non-nuclear technologies, they require particular attention for an NPP in order that the owner/operator can ensure and demonstrate to the regulator safe and secure operation.

For the main NPP contract, depending on the overall contracting strategy, knowledgeable costumer activities can include the development of bid invitation specifications and evaluation criteria, evaluation of bids and award of contract(s), agreement of contract specifications, oversight of construction, auditing of the vendors' supply chain management processes and supplier visits, and witnessing the manufacture of key components. The process of managing the construction contract is addressed in Section 3.3.

Once the plant is built, the owner/operator will need to have in place a significant procurement and engineering capability to manage the ongoing procurement of consumables, replacement parts and repairs.

Besides procurement of equipment, there is also a need to procure services in all three phases. These cover specialist advice, such as to the NEPIO, specific activities such as siting and grid analysis as well as support for specialist inspections and assessment. Both the owner/operator and the regulator will need processes to manage the procurement of specialist services, and it is important that they have the capabilities to specify the quality requirements and verify that the supplier meets those requirements (i.e. the knowledgeable customer role). Organizations will also need to ensure that the national legislation is consistent with the need to procure specialist services from other countries.

3.19.1. Procurement: Phase 1 — Considerations before a decision to launch a nuclear power programme is taken

As noted in Section 3.3.2, the NEPIO will define the strategy for developing contract arrangements for the NPP. It will need to identify the capabilities and processes that will be required to implement the procurement processes both for the NPP and the associated services.

The NEPIO itself may need to procure services to support the development of the prefeasibility studies or the preparation of the comprehensive report in areas of competence not available.

3.19.2. Procurement: Phase 2 — Preparatory work for the contracting and construction of a nuclear power plant after a decision has been taken

Depending on the chosen procurement strategy, the owner/operator may need to conduct a competitive bidding process to select a vendor. This will involve the development of bid invitation specifications and bid evaluation criteria. Even when the vendor has been preselected, the owner/operator will need to define contract specifications and evaluation criteria for negotiating with the chosen supplier.

In addition to procuring the NPP, the owner/operator will need to establish a procurement capability for certain services. It should develop the capability to procure required services for pre-project activities (e.g. EIA, siting, consulting), to achieve the following in particular:

— Ensure that suppliers have appropriate expertise and experience;
— Prepare formal specifications for the services required;
— Include quality standards in the service specifications.

3.19.3. Procurement: Phase 3 — Activities to implement the first nuclear power plant

The owner/operator needs to develop the capabilities and processes to negotiate a commercial contract with the selected vendor.

In preparing for NPP operation and maintenance, the owner/operator will need to establish its own procurement function and establish suitable arrangements to procure, receive, control, store and issue materials (including supplies), spare parts and components. In doing so, it should consider not only procurement for normal operation and for emergency equipment to be pre-positioned on site, but also procedures for the urgent procurement of additional supplies and equipment as needed in emergency situations. To prepare for such activities, it is recommended that the owner/operator develop a plan to ensure that the required competence and procedures are available before the end of Phase 3. Part of this should include arranging for procurement staff to work alongside the supplier procurement team to gain the experience required.

The procurement function will require both procurement skills and engineering skills. The main tasks under this function are as follows:

— Identifying the appropriate technical, quality and commercial requirements;
— Undertaking supplier audits and witnessing;
— Maintaining approved supplier lists;

— Defining and applying acceptance criteria;
— Receipt inspection and testing;
— Storage and warehousing.

A document management system needs to be established to create, store and maintain necessary documents to support the procurement process. This typically includes a full list of components installed in the facility, their criticality to plant safety or economic operation, spare parts listings, drawings, specifications and maintenance manuals. The ability to track items from original suppliers through to plant installation locations needs to be established. Such data requirements should be included in the contract arrangements and included in formal documentation to be provided to the owner/operator towards the end of Phase 3.

Software and digital equipment are increasingly being used in the nuclear industry. The owner/operator needs to put processes in place to request declaration of any software or digital equipment included within vendor products, to qualify and control such software, and to address computer security issues within procurement requirements.

Counterfeit or fraudulent items are another potential problem for the nuclear industry. The owner/operator needs to put processes in place to detect and report suspected items. These include ensuring good knowledge of supply chain participants, putting processes in place to transmit requirements down the supply chain, and monitoring and evaluating supply chain performance.

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Annex

INFRASTRUCTURE CONSIDERATIONS FOR SMALL MODULAR REACTORS

A–1. BACKGROUND

In addition to the ongoing work in countries developing small and medium sized or modular reactors (SMRs), including design development, design certification, and deployment and demonstration of the first of a kind (FOAK) design, there is a growing interest on the part of embarking and expanding countries in the potential use of SMRs. This interest may be attributed to two factors:

— The lower upfront capital required to finance SMRs and, for some designs, the possibility to scale the acquisition of modules as the demand for electricity increases with time;
— The size of the electrical grid, which in some countries cannot accommodate a large nuclear power plant (NPP).

This annex deals with infrastructure considerations for a nuclear power programme where the preferable technology is an SMR. As there are numerous SMR designs in different stages of development, with varying power output capacities and different uses[1], the subset of SMRs considered in this annex are those that are in advanced stages of demonstration and are likely to be commercially deployed in embarking and expanding countries by 2030 (following completion of design, testing, construction, and demonstration of a pilot unit). This subset of SMRs is based on well known technologies (pressurized water reactors, boiling water reactors or high temperature gas cooled reactors) with evolutionary design features such as reliance on passive systems and a higher level of automation when compared with the current large NPPs.

Several meetings were convened by the IAEA to discuss the applicability of the Milestones approach for a nuclear power programme based on this subset of SMRs. It was concluded that the Milestones approach remains applicable, as the infrastructure of an SMR is, to a large extent, similar to that required for

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Advances in Small Modular Reactor Technology Developments, A Supplement to: IAEA Advanced Reactors Information System, 2022 Edition, IAEA, Vienna (2022), https://aris.iaea.org/Publications/SMR_booklet_2022.pdf

large NPPs. However, it is expected that some elements of the infrastructure can be downscaled, as the power and risks associated with an SMR are smaller compared to those associated with a large NPP.

It should also be mentioned that Fig. 1 (given in Section 2.1) suggests that the duration of a nuclear power programme, from its initial consideration to the point where all infrastructure is ready to start operation, may vary between 10 and 15 years depending on the resources available with a Member State. This timeframe is expected to be shorter for an SMR, as the infrastructure to be developed in Phase 2 can, in some cases, be downscaled and the construction time in Phase 3 is shorter. However, there are still no data available to confirm these assumptions.

A–2. UNIQUE FEATURES OF SMALL AND MEDIUM SIZED OR MODULAR REACTORS

SMRs are said to exhibit some or all the following attributes:

— Greater simplicity of design;
— Serial production, largely in factories;
— Smaller power output;
— Installed module by module with multiple units on the same site;
— Shorter construction times;
— Applicability to countries with smaller grids;
— Easier financing due to reduced front end capital required and construction efficiency;
— Ability to remove reactor module or in situ decommissioning at the end of life;
— Smaller source term, which allows for a less demanding infrastructure, in particular for emergency preparedness and response (EPR).

A–3. IMPACT OF FEATURES AND DEPLOYMENT MODELS OF SMALL AND MEDIUM SIZED OR MODULAR REACTORS ON THE INFRASTRUCTURE ISSUES

This section presents how some aspects of nuclear infrastructure may be implemented differently for SMRs. This difference can result from SMR features or from deployment models proposed by technology providers.

A–3.1. National position

Private companies may have more enthusiasm for SMR projects as developers and promoters. However, governments still need to lead the development of a national strategy for the nuclear power programme; commit on the development, implementation and maintenance of a safe, secure and sustainable nuclear power programme which is in line with international norms and standards; and meet the international obligations of the State.

Energy planning studies might cover a broader range of energy needs beyond electricity, such as district heating and cooling, process heat and desalination, depending on the uses envisaged for the SMRs. It is expected that the energy planning will take into account commitments with decarbonization goals of the economy and with environment, social and governance criteria.

A coordination mechanism, or a nuclear energy programme implementing organization (NEPIO), is still needed to ensure that prefeasibility studies are consistent and to lead the development of a comprehensive report that justifies the development of a nuclear power programme in the country.

Stakeholders of the NEPIO may include other entities. This may be the case when the project developers are private companies or, if the SMRs are planned to be utilized for non-electrical applications where the involvement of other regulatory authorities may be required.

If the decision to move forward with the nuclear power programme is taken, policies and strategies still need to be developed in areas such as nuclear safety, human resources development, fuel cycle, waste management and industrial involvement.

By the end of Phase 3 it is expected that all elements of the infrastructure will be in place, with a competent owner/operator and regulatory authority. As in the case of a programme based on large NPPs, consideration should be given to the sustainability of the programme in the long term.

A–3.2. Nuclear safety

It is expected that SMR designs will be simpler and employ passive safety systems to a larger extent. However, a design that facilitates nuclear safety does not eliminate the need for effective leadership and infrastructure that ensures vigilance.

Understanding and participating in the international framework for safety remains an important element for a programme based on SMRs. This includes building and maintaining a culture for safety in all relevant organizations, fulfilling the obligations of relevant international legal instruments and joining associations of operators and regulators.

The capacity to perform safety assessments and inspections remains critical for both the regulatory body and the owner/operator, and those competences need to be developed and maintained.

In developing its regulations and guides for safety, the regulatory authority and owner/operator should develop a detailed understanding of the IAEA safety standards and their applicability for SMRs, and its licensing process should use, to the extent possible, the experience of a senior regulator that has licensed a similar reactor.

As for large NPPs, it is expected that the owner/operator will establish mechanisms to maintain the knowledge of the safety design and its configuration management over the lifetime of the SMR.

A–3.3. Management

Management of a nuclear power programme based on SMRs remains demanding; highly competent managers are vital to success at all stages and the NEPIO remains a key coordination mechanism with the required competences to oversee the development of the programme. Managers of key organizations still must develop the organizations, establish management systems, build project management capabilities, develop technical specifications, negotiate contracts, among other tasks.

No significant differences are identified from the project management perspective. However, some observations include the following:

— The development of the regulatory body and the owner/operator in Phases 2 and 3 needs to be accelerated considering the expected shorter construction and commissioning time.
— The human resources of the owner/operator will be reduced when compared with a large NPP, however the competences required remain largely the same.
— Manufacturing oversight may require a different approach if prefabricated modules are proposed.

A–3.4. Funding and financing

The responsibilities of the government to fund the development of the national infrastructure required for a nuclear power programme remains relevant. Funding includes the costs associated with the development of human resources, establishment of the regulatory body and of the owner/operator (if it is a State owned organization), and building of the legal and regulatory framework. It also includes the costs to implement site related activities and the establishment of

the infrastructure for EPR, radiation protection, safeguards, waste management and environmental protection. It is expected that the costs of some infrastructure elements mentioned above will be lower owing to the more limited arrangements required. Arrangements also need to be developed for funding of radioactive waste management and commissioning.

The lower upfront capital requirements and the possibility to phase the financing of additional SMRs or SMR modules can facilitate the financing of nuclear power in embarking countries. This has already resulted in an increase in the interest of private capital and institutional investors towards SMRs. In some cases, those private investors took the lead in initiating the discussions on the nuclear power programme.

A–3.5. Legal framework

The main elements will remain the same, as the legal framework defines the responsibilities of all organizations necessary for any nuclear power programme. It comprises three main elements: international legal instruments, comprehensive national nuclear law, and other legislation that can have an impact on the nuclear power programme. The international agreements set out legal norms in the areas of nuclear safety, security, non-proliferation, and liability that apply to SMRs as well as to conventional NPPs. National laws reflect these international norms.

Some SMR designs, such as those where a fuelled reactor is transported to or from the country of origin for refuelling or for maintenance, may require some additional legislation and/or adherence to other international legal instruments, such as the International Maritime Organization (IMO) conventions.

A–3.6. Safeguards

Through a number of international, regional and bilateral instruments, most Member States of the IAEA have undertaken to accept the application of safeguards to nuclear material and activities under their jurisdiction or control. Pursuant to the safeguards agreements concluded with the IAEA, each State enacts measures for accounting for and control of nuclear material, containment and surveillance, and inspection. These measures apply to all uses of nuclear material, whether used in a conventional NPP or an SMR.

However, the practical implementation of safeguards by the State party and the IAEA may require the development of new approaches depending on the SMR design and the type of fuel. In that regard, early consultation with the IAEA is advisable, as is considering the implementation of safeguards at the design stage (i.e. safeguards by design).

The understanding of safeguards requirements by technology providers is critical for international deployment.

A–3.7. Regulatory framework

The elements of the regulatory framework remain the same: to establish a regulatory body with the required competences for licensing and overseeing construction and operation, and to develop regulations and guides and internal processes to conduct all licensing steps.

For large NPPs, embarking countries have either adopted technology neutral regulations based on the IAEA safety standards and Nuclear Security Recommendations to allow for competitive bidding or have developed regulations in line with those of the vendor country, where the vendor has been chosen early on via an intergovernmental agreement. Those regulations are, in general, complemented by technology specific guides (and industrial codes and standards) from the country of origin of the technology or from a country that has adopted a comparable technology. Similar approaches are likely to be adopted by countries interested in SMRs for their nuclear power programmes.

The practice used by some embarking countries of mutual recognition of licensing decisions between the recipient country and a country that has licensed a similar facility is expected to remain relevant as a facilitator for SMR deployment and a basis for deep understanding of the safety case for the specific technology to be deployed.

The vision of international harmonization, based on common regulatory and technical standards, is promoted by some industry organizations to facilitate the licensing process in embarking and expanding countries. This is not unique to SMRs, as the same proposals have been promoted for many years for large NPPs. This vision will require time to be achieved and it needs to be addressed at several levels:

— Legal framework (governments);
— Licensing and regulatory guides (nuclear regulators);
— Codes and standards of practice (industry).

The IAEA is working on evaluating the adequacy of the IAEA safety standards for SMRs. This may lead to the development of further guidance if substantial differences are observed. It is expected that this work will be largely completed at the time SMRs will be offered on a commercial basis to embarking or expanding countries (or technology recipient countries).

A–3.8. Radiation protection

All embarking and expanding countries already have a radiation protection infrastructure for workers and members of the public for the existing activities using or generating ionizing radiation. Appropriate expansion needs to be considered to cater to the special needs of a nuclear power programme.

The elements of the radiation protection infrastructure are the same for a large NPP or for an SMR. It includes development of regulations and guides, development and implementation of radiation protection programmes for workers and public, and recruitment and training of radiation protection staff. However, owing to the smaller size and lower risks associated with SMRs, it is possible that some elements of the infrastructure for radiation protection will require less expansion.

A–3.9. Electrical grid

Small modular reactors (and large NPPs) may serve various purposes, including desalination, district heating and electricity generation. The topic of the electrical grid in this annex covers only the aspects related to the connection of SMRs to the country's electrical grid.

In general, it is recommended that the power of a single unit not exceed 10% of the overall installed capacity of the grid to avoid voltage and frequency fluctuations that could lead to grid shutdown in the case of a unit trip. This requirement remains valid for SMRs as well. This makes SMRs easier to install than large NPPs in countries with small electrical grids. Availability of a local or integrated grid will still be needed to evacuate the electricity generated.

For large NPPs, electricity from the grid is always needed for essential safety functions. Some SMR designs may not need to have a reliable off-site power supply to ensure safety, as those designs do not require active systems and the overall safety of the plant can be guaranteed by passive systems that do not require off-site power supply. However, attention still should be paid to the supply of power, especially for severe accident management where the lighting and monitoring systems are needed to cope with the situation. Off-site power should always be considered as the preferred power supply to NPPs, including SMRs.

Considering the above, grid studies and enhancements may be less complex and demanding. However, the grid still needs to reliably dispatch and evacuate the electricity produced and minimize the number of reactor trips.

A–3.10. Human resource development

In Phase 1, it is expected that the embarking country will identify the range of competences needed in different areas (i.e. scientific, technical, managerial, and administrative), develop a national human resources management strategy to identify the approach to developing and recruiting the skills required, and analyse the existing academic system to identify the necessary improvements. This may lead to the creation of new courses and/or the expansion of existing ones that will be implemented later in the programme.

In Phases 2 and 3, it is expected that key organizations will have identified the competences needed and will establish appropriate recruitment and training programmes to ensure that competent organizations are in place.

Preliminary considerations show that the range of competences required remain the same independent of whether a large NPP or an SMR is being considered. From the workforce planning perspective, while the number of staff in the owner/operator may be reduced, this is likely not the case for the NEPIO or the regulatory body. This might lead to overall lower resources required for the owner/operator in the case of an SMR deployment.

As the logic in the Milestones approach is that the embarking country will adopt an engineering, procurement and construction (EPC) contract, the workforce for construction is under the contractor's responsibility and is therefore not covered here.

The building of competences in the regulatory body and in the owner/operator needs to be accelerated due to the projected shorter construction time.

A–3.11. Stakeholder engagement

Stakeholder engagement is intended to address concerns early and to explain the nuclear power programme rationale, plans and progress. The main stakeholders in a nuclear power programme include legislators, different ministries, academia, the regulatory body, the future owner/operator, local industries and the general public.

Stakeholder engagement is very important for nuclear power programmes with large NPPs and remains so for SMRs as well. Depending on the nature of the project (i.e. public or private), other organizations may become stakeholders.

Public acceptance is paramount for a successful nuclear power programme, and performing surveys and organizing awareness activities on the risks and benefits of SMRs should be planned by all key organizations (i.e. NEPIO, regulatory body and owner/operator).

A–3.12. Site and supporting facilities

The activities involved in choosing a site and obtaining authorization by the regulatory body for the construction of an NPP include site survey, site selection, site characterization and preparation, and submission of a site evaluation report to the regulatory body. This is followed by an assessment of the site evaluation report by the regulatory body and either the final acceptance of the site or a statement of non-objection, depending on the regulatory framework of the country. This process remains valid in case of SMRs.

It is expected that, owing to the smaller source term and the lower demand on cooling water (dry cooling may be applied), there will be a higher number of acceptable sites. It may also be expected that technology developers will apply higher safety margins to the design, which can lead to the deployment of a standard design to a broader range of site conditions.

There could be a reduced demand for supporting facilities that need to be planned and built to accommodate construction workers and allow access to services. However, there may be SMRs with large prefabricated modules that may require special transportation considerations.

Several concepts propose underground reactor placement; in such cases, further underground investigations will be needed.

A–3.13. Environmental protection

Environmental protection includes the national infrastructure needed by a nuclear power programme to ensure protection of the environment, as well as the studies and activities undertaken to assess, mitigate and manage impacts on the environment.

Many countries require a comprehensive environmental impact assessment (EIA) to be conducted in accordance with national requirements at the project level before a final decision is taken on siting and construction of the facility. Some countries may also require or encourage a strategic environmental assessment (SEA) at the nuclear power programme level to be conducted in the earlier phases of the programme.

These environmental protection activities apply for large NPPs and SMRs. The total number of modules/units planned needs to be considered in the application for the environmental authorization.

A–3.14. Emergency preparedness and response

Emergency preparedness and response is the last layer in the defence in depth principle and is intended to address accident situations that may

occur at the facility. Emergency planning is done on the basis of deterministic considerations which may be complemented by probabilistic studies. Planning is based on a reasonable selection of scenarios and measures taken at the other levels of defence in depth. This approach is applicable to any nuclear installation, including SMRs.

Emergency preparedness and response consists of two main elements: on-site arrangements and off-site arrangements. It is possible that, owing to the lower source term of SMRs compared with large NPPs, the required off-site arrangements can be more limited, for example a smaller emergency planning zone, depending on local regulations. On-site arrangements will continue to require, among others, trained staff, accident procedures, and exercises and drills.

Even with the more limited arrangements, the involvement of other organizations such as crisis management organizations, civil defence and hospitals is still needed and should be part of the off-site emergency plan.

A–3.15. Nuclear security

Nuclear security concerns the prevention and detection of and response to intentional unauthorized acts that may lead to an accident or the theft of nuclear material. Arrangements may include several organizations, including the government, regulatory body, owner/operator, intelligence forces and police.

A legal and regulatory framework needs to be established, a national threat assessment and design basis threat need to be developed early in the programme and physical protection systems need to be designed and implemented. All these elements are needed for projects based on large NPP technology as well as projects based on SMR technology. Some SMRs may consider the principle of security by design, thereby creating inherent security through design features.

It is not clear if the security arrangements for SMRs may be simplified. Obviously, owing to the higher level of digitalization, cyber security will remain very important.

A–3.16. Nuclear fuel cycle

A country starting a nuclear power programme should define its fuel cycle strategy early as it may influence the support to be negotiated with the technology provider.

The nuclear fuel cycle has two components: the front end and the back end. The experience gained with embarking countries shows that, for the front end, assurance of fuel supply is a major consideration. Typically, the initial fuel load and several reloads are included in the EPC contract, while fuel supply for the long term is ensured through one or several additional contracts. Currently,

no embarking country has considered the development of uranium enrichment or the manufacture of nuclear fuel components as part of their nuclear power programme.

The back end considers on-site and off-site storage of spent fuel, and the potential reprocessing of used fuel in the country of origin.

The elements described above remain valid for SMRs where the aspects related to an early strategy, both for the front end and the back end, are needed for discussion and choice of the preferred technology. However, considering that some SMR designs foresee different types of fuel, the availability of corresponding suppliers needs to be ensured.

It is not clear (at least for some designs) how technology providers are considering the services for the front end that are needed in recipient countries.

A–3.17. Radioactive waste management

This issue addresses the required infrastructure to manage all radioactive waste generated by the NPP, including waste from spent fuel that is reprocessed or spent fuel that is not reprocessed. Depending on the SMR technology, new forms of radioactive waste may be generated, in particular for non-water cooled SMRs.

Infrastructure activities for radioactive waste management include an assessment of the existing repository facilities and the need for their expansion. It also includes an assessment of the existing technological options for processing and storage of radioactive waste both on-site and off-site.

Small and medium sized or modular reactors, like any nuclear installation, will generate low, intermediate and high level radioactive waste (in the case that spent fuel is declared as waste) and the above considerations on infrastructure remain pertinent. The volume of radioactive waste generated will probably be smaller, and this may lead to a more limited expansion of the existing facilities. Considerations on radioactive waste generated by decommissioning will depend on the deployment models proposed by the technology providers.

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention) stipulates that radioactive waste should be disposed of in the country in which it is generated. However, it also allows the possibility of waste being disposed of elsewhere in the interests of safety and efficiency. Adherence to the Joint Convention is still needed in the case of SMRs.

A–3.18. Industrial involvement

This issue is related to the participation of local industries and companies in the nuclear power programme to foster the creation of jobs and economic growth.

The concept of standardization and off-the-shelf prefabricated reactors, proposed by some SMR designers, may limit the possibilities of localization. However, the lower pressure and temperature applied for major components can make it feasible to fabricate them in existing industrial facilities.

The Milestones approach suggests the development of a policy on industrial involvement early in the development of the nuclear power programme as well as a strategy to achieve those goals. It is also suggested that the work start with a survey of the industry to evaluate the interest of the industry and to inform it on the quality standards that nuclear power project requires. These activities apply equally for a large NPP and for an SMR.

A–3.19. Procurement

Procurement is about procuring the NPP and supporting services, and establishing procurement capabilities in the owner/operator organization. The development and evaluation of bids, including defining technical specifications and contract negotiations, are major tasks in Phases 2 and 3. The procurement of the plant should not overshadow the procurement capabilities requested for other goods and services in all organizations.

All these remain valid for a nuclear power programme based on SMRs. It is possible that the size of the procurement team in the owner/operator organization may be reduced.

Procurement of technical support by the regulatory body remains the same.

ABBREVIATIONS

CSA	comprehensive safeguards agreement
EIA	environmental impact assessment
EPC	engineering, procurement and construction
EPR	emergency preparedness and response
HLW	high level waste
ILW	intermediate level waste
Joint Convention	Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management
LLW	low level waste
NEPIO	nuclear energy programme implementing organization
NPP	nuclear power plant
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
SEA	strategic environmental assessment
SMR	small and medium sized or modular reactor
SQP	small quantities protocol
SSAC	State system of accounting for and control of nuclear material

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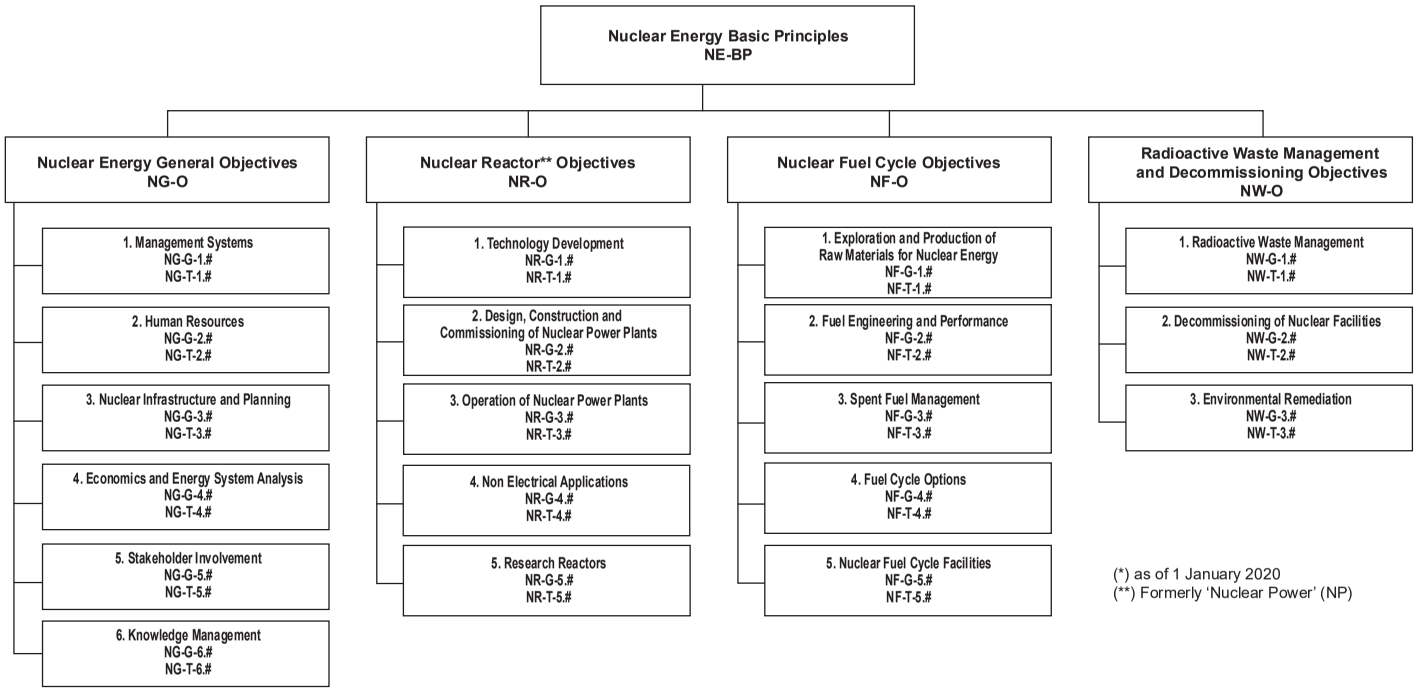

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International Atomic Energy Agency
Vienna, 2024
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