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SPECIFIC CONSIDERATIONS AND MILESTONES FOR A RESEARCH REACTOR PROJECT

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IAEA NUCLEAR ENERGY SERIES No. NP-T-5.1

SPECIFIC CONSIDERATIONS AND MILESTONES FOR A RESEARCH REACTOR PROJECT

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2012

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International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
June 2012
STI/PUB/1549

IAEA Library Cataloguing in Publication Data

Specific considerations and milestones for a research reactor project. — Vienna : International Atomic Energy Agency, 2012.
p. ; 29 cm. — (IAEA nuclear energy series, ISSN 1995–7807 ; no. NP-T-5.1)
STI/PUB/1549
ISBN 978–92–0–127610–0
Includes bibliographical references.

1. Nuclear reactors — Research. 2. Nuclear reactors — Design and construction. 3. Nuclear reactors — Safety regulations. I. International Atomic Energy Agency. II. Series.

IAEAL 12–00740

FOREWORD

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

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

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

Services provided by research reactors can impact every aspect of social and community development. Research reactors can contribute to a country's scientific and educational resources, raise living standards through improved health care and industrial and agricultural productivity, or pave the way to the utilization of nuclear energy. However, the decision to construct a new research reactor requires national recognition of international responsibilities and the implementation of essential policy and technical infrastructure. If appropriately conceived, managed and organized, a research reactor can be an extraordinary tool with capabilities that include training, human resources development, research and technology, testing of materials, radioisotope production (for industrial and medical applications), and other commercial applications. In the absence of such planning, a research reactor is unlikely to reach its full potential and could present challenging, long term issues, including issues concerning financial support.

The complexity of the infrastructure issues associated with a new research reactor depends upon the type of research reactor selected, the scope of any pre-existing nuclear infrastructure in the country, and the availability of human and technical resources. To facilitate comprehension of these issues, the IAEA has established four distinct phases of research reactor implementation. This publication describes the four phases of the implementation programme and provides guidance on the timely preparation of a research reactor project through an easy to understand sequential development process. It includes a detailed description of the range of infrastructure issues that need to be addressed and the expected level of achievement (or milestones) at the end of each phase.

This publication can be used by Member States to assess their own status with regard to justification and resourcing for a research reactor, as well as the development of the necessary supporting infrastructure. It will enable them to prioritize the activities required to order, license, construct and then safely operate the research reactor. This guidance aims to help Member States understand their commitments and obligations associated with a research reactor programme, and clarifies that the responsibility for safe implementation of a research reactor programme rests with the Member State and its organizations and cannot be subcontracted or avoided.

Other organizations such as donors, suppliers, nuclear energy agencies and utility organizations may also find this publication useful as a basis for project assessment. Such assessments could build confidence that the country has the ability to legislate, regulate, construct, and safely and securely operate a research reactor.

The IAEA officers responsible for this publication were P. Adelfang, J.H. Phillips and K. Alldred of the Division of Nuclear Fuel Cycle and Waste Technology, and H. Abou Yehia and A.M. Shokr of the Division of Nuclear Installation Safety.

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SUMMARY

This publication is written for Member States considering a new research reactor. It will be of most use to decision makers, advisers and senior managers in the governmental organizations, research institutes, and regulatory bodies of those Member States. This publication can be used to identify the best practices for a research reactor programme, ensuring that the responsibilities and issues inherent in the various phases of the research reactor project are understood and taken into consideration at the start of the project.

The utilization and justification for a research reactor is discussed in Section 2 of this report. This first, essential step will highlight the important policy issues, and determine the size, type, power level, and uses of the research reactor. It will also help to build a firm basis of the stakeholder support needed for the research reactor, and highlight issues that require policy or governmental action during project implementation. Research reactors are great machines that can supply: training to support a nuclear power programme; materials research; biological research; medical and industrial isotopes; and other services. However, with the exception of very small university research reactors, a research reactor project represents a budget liability that may extend for 100 years or more, when the infrastructure development, planning, purchase, construction, operation, decommissioning, waste, and spent fuel disposition are considered. In the past, some Member States have not adequately funded research reactors resulting in extended shutdown periods, inadequate maintenance, and an increased hazard to Member States. Although a research reactor project may be championed by an institute, university or corporation, it is the Member State that must accept the ultimate liability for the reactor, its spent fuel and waste.

It is a major undertaking to determine the potential utilization of the research reactor. The value or benefits of a research reactor's non-destructive examination capabilities may not be known by potential users; for example, the medical community may not be fully aware of the possibility to obtain radioisotopes for the diagnosis and treatment of diseases; and universities or researchers may not understand how a research reactor can be used to investigate biological processes, and for groundwater studies, atmospheric studies, etc. An Assessment, Marketing and Project Team (AMPT) should be established to identify all the reactor's potential stakeholders and assess their needs. These include: measurement capabilities, the types and quantities of isotopes, number and types of neutron beams, the types of processing facilities, etc.

Section 3 provides an overview of the research reactor project phases and associated milestones, which are based upon those described in IAEA Nuclear Energy Series No. NG-G-3.1 entitled Milestones in the Development of a National Nuclear Infrastructure for Nuclear Power. It should be noted that a research reactor project requires the same scope of infrastructural support as a nuclear power reactor, and many Member States have benefited from a research reactor as a stepping stone to a nuclear power reactor. The research reactor infrastructure can be subsequently expanded to accommodate a nuclear power programme. There are however, differences in the utilization and extent of the infrastructure, depending upon the type, size and ancillary facilities of the research reactor. Security, safeguards, and safety for a research reactor can be a special issue because of the potentially hazardous isotope inventory and because they are often located in universities and research settings and managed by an academic staff not otherwise accustomed to dealing with hazards of this magnitude.

The report discusses the 'graded approach' to infrastructure utilization and extent in which the risk assessment of the research reactor project is used to determine the appropriate infrastructure for the research reactor.

A discussion of the milestones for a research reactor project is given in Sections 4–6 of this report, adapted from IAEA Nuclear Energy Series No. NG-G-3.1 for a complete and up to date understanding of the infrastructure needs for a research reactor, this report may be used in conjunction with the latest version of IAEA Nuclear Energy Series No. NG-G-3.1.

The annexes to this report provide a brief discussion of research reactor sizes and uses, alternatives to a research reactor, and a regional approach to a research reactor.

1. INTRODUCTION

1.1. BACKGROUND

A research reactor project is a major undertaking requiring careful planning, preparation and investment in time, money, and human resources. It requires strict attention to nuclear safety, international safeguards, nuclear security, and the control and accounting of nuclear materials. In turn, these create a requirement for government oversight and funding that extend well beyond the usual timescales for a capital project of similar size. The issue is made more complex for many research reactors because of the diversity of stakeholder interests, and the evolution of the research reactor's mission over time, coupled with an inability to self-fund operations, maintenance, waste management and decommissioning. The management of these complexities set the research reactor programme apart even from other nuclear energy projects.

The decision by a Member State to embark on a research reactor project should be based upon a justified need for the capabilities of the research reactor. This also includesa commitment to use it for peaceful purposes; safely, securely, and demonstrably in compliance with international legal instruments (treaties, conventions, etc.), IAEA safety standards, security guidelines and safeguards requirements. This commitment is a responsibility not only to the Member State's own citizens, but also to the international community. To discharge that responsibility, the Member State requires a sizeable, sustainable national infrastructure to provide governmental, legal, regulatory, managerial, technological, human and industrial support throughout the research reactor life cycle.

To be ready to invite bids for a research reactor, the Member State should fully understand the commitments required at all stages of the research reactor project and have mechanisms to meet those commitments. The plans and funding mechanisms for operation, regulation, decommissioning, spent fuel and waste management, should be in place before a research reactor bid request is issued.

The development and implementation of the supporting infrastructure for a first research reactor is an issue of central concern. The infrastructure is wide ranging, and includes the physical facilities and equipment associated with the research reactor, the transportation of nuclear materials and supplies, and the handling of spent fuel and radioactive waste materials. It also includes the legislative and regulatory framework, and the human and financial resources to ensure safe, secure, peaceful and efficient construction and utilization of the reactor throughout its life cycle. In short 'infrastructure', as used in this publication, includes all activities and arrangements needed to set up and operate a research reactor.

The research reactor programme starts with a justification for the research reactor based on the national or regional needs for research reactor services, the availability of alternatives, and the availability of sufficient financial, technical and human resources. The latter point is of particular importance. Experience shows that a research reactor is unlikely to fully pay for itself and thus must be supported, in whole or in part, by public funds throughout its lifetime. This funding requirement includes the costs of the planning process, bid development, facility construction, commissioning, operation, and decommissioning of the research reactor; the storage and disposition of its radioactive wastes and spent fuel, and the infrastructure maintenance throughout the reactor life cycle. Consequently, the commitment of public funds will be several decades in duration and requires a careful and systematic assessment before the project starts.

The fundamental nuclear safety objective is to protect people and the environment from harmful effects of ionizing radiation. A comprehensive safety framework should be developed that permeates all programme activities and embodies the ten safety principles discussed in IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles [1]. The first principle is that the prime responsibility for safety rests with the operating organization. The Member State should ensure that the operating organization develops and enforces good safety and security cultures throughout the entire programme.

No less significant are the issues associated with the safe and secure control of nuclear and radioactive material. Systems and practices are required to demonstrate that that all such materials are adequately accounted for and protected, and that there is no risk of proliferation of nuclear or radiological weapons.

1.2. OBJECTIVES

This publication will assist a Member State that is considering the construction of a research reactor to:

(1) Judge its own status and readiness to introduce a research reactor;
(2) Determine the magnitude of the commitment necessary to ensure that it is fully prepared to achieve the peaceful use of research reactor in a safe, secure and technically sound manner;
(3) Ensure the efficiency and success of its research reactor, and avoid future underutilization issues with the facility.

Decision makers, advisers and senior managers in the governmental organizations, academic and scientific institutions, industries, and regulatory bodies of a Member State interested in constructing a research reactor may use this publication to identify the various sequential activities required to plan, purchase, build, operate and ultimately decommission a research reactor.

Other organizations, such as donors, suppliers, universities, research companies, and technical support organizations, may use this publication to derive confidence that the country has the infrastructure necessary to regulate, construct and safely operate a research reactor, or to identify areas for potential assistance.

The IAEA may use this publication to help determine the degree of a Member State's progress in developing the justification for a research reactor and implementing the infrastructure needed to support it so that assistance can be provided in a meaningful and timely manner.

1.3. SCOPE

This publication provides a discussion of the mechanisms for justification of a research reactor, and for building stakeholder support. It also presents a framework of milestones in the development of a national nuclear infrastructure, such that the Member State can confirm that it has:

(1) A justified need for a research reactor;
(2) Comprehensively recognized and identified the national and international commitments and obligations associated with the construction of a research reactor;
(3) Established and adequately prepared the national infrastructure prerequisite to the construction of a research reactor;
(4) Established all the competences and capabilities necessary to regulate and operate a research reactor safely, securely and economically over its lifetime, and to regulate and manage the ensuing radioactive waste;
(5) Established adequate funding and review mechanisms adequate for the research reactor project throughout its life cycle.

The scope of the publication includes both the 'hard' (facilities) and 'soft' (legislative, regulatory, training, etc.) infrastructure items needed for a research reactor, and the evolution of infrastructure needs from the time a Member State first considers a research reactor and its associated facilities, through the stages of planning, bid preparation, construction, startup, and preparation for commissioning.

The subsequent stages of operation, decommissioning, spent fuel and waste management issues are addressed in this publication to the degree necessary for appropriate planning prior to research reactor commissioning.

The information presented in this publication is based on the experience and good practices of countries with research reactors and is not intended to impose standards on those contemplating a new research reactor.

1.4. STRUCTURE

This publication consists of the following main sections in addition to this introduction:

— Section 2 sets out the three major infrastructure milestones for a research reactor project;

— Section 3 discusses the very important considerations of the research reactor justification, the determination of the need for the research reactor, who will use it, and how it will be financed and managed;
— Sections 4–6 provide detail for the three primary infrastructure milestones in terms of 19 infrastructure issues.

The appendix summarizes the milestones conditions in tabular form and provides an overview of the supporting activities for each milestone.

The annexes discuss the sizes and uses of research reactors, alternatives to a research reactor, the regional versus national approach to construction and operation of a research reactor.

1.5. USE

This publication should be used as an aid in planning and implementing a research reactor project, and for ensuring that an appropriate national infrastructure exists to support it. This report presents mechanisms for developing the justification and stakeholder base for a research reactor, to ensure that it does not become underutilized and thereby a potential cause for concern on safety or security grounds, and it presents a checklist of infrastructure elements that should exist at appropriate times during the development process. A wealth of information and guidance on each of the issues included in infrastructure development is available in IAEA publications listed in the Bibliography.

1.6. THE CODE OF CONDUCT FOR THE SAFETY OF RESEARCH REACTORS

The Code of Conduct on the Safety of Research Reactors provides guidance on the development and harmonization of laws, regulation and policies on the safety of research reactors. It provides ‘best practice’ guidance to the State, the regulatory body and the operating organization for management of research reactor safety. In accordance with resolution GC (48)/RES/10 on Measures to Strengthen International Cooperation in Nuclear, Radiation and Transport Safety and Waste Management, Member States are encouraged to use the Code of Conduct on the Safety of Research Reactors as the basis upon which to regulate and conduct research reactor activities.

The provisions of the Code of Conduct should be applied from the start of the research reactor project and accomplished through national safety regulations pertaining to all stages in the life of research reactor. Member States are recommended to make appropriate use of the IAEA Safety Standards relevant to research reactors and those relating to the governmental, legal and regulatory framework for safety.

1.7. RESEARCH REACTOR UNDERUTILIZATION

Nearly 50% of the operational research reactors listed in the IAEA Research Reactor Database [2] in 2010 were operated for one full power month, or less, each year. Underutilized research reactors not only waste resources but they can also become a safety, security and environmental hazard if there is an associated shortfall in maintenance funding.

There are several common reasons for low research reactor utilization, including:

(1) The reactor was built as a ‘national prestige’ project without a clear understanding of its intended uses or need;
(2) The initial purpose of the research reactor has become obsolete, and mechanisms do not exist to refresh or update the reactor mission;
(3) Organizational and financial restrictions make it difficult for the reactor operator to develop alternative uses of the reactor;
(4) The organizational environment in which the reactor must operate creates conflicts between management and the funding bodies for the reactor, or between the reactor mission (for example, irradiation services and isotope production) and the reward structure for its staff (for example, publication of scientific papers).

These issues are amongst those reviewed in the IAEA publication Status of Nuclear Research and Development Institutes in Central and Eastern Europe [3]. The issue of research reactors in extended shutdown state is also discussed in the IAEA publication Safety Considerations for Research Reactor in Extended Shutdown State [4]. Consideration of such issues during planning for the research reactor should help to avoid future underutilization problems.

2. THE INFRASTRUCTURE DEVELOPMENT MILESTONES

2.1. INFRASTRUCTURE REQUIREMENTS

A research reactor must be supported by a specialized infrastructure. Many of the issues presented by a research reactor are similar to those of a nuclear power plant (NPP). Consequently, the infrastructure needs for research reactors are similar to those for NPPs as discussed in the IAEA publication Milestones in the Development of a National Infrastructure for Nuclear Power [5]. The infrastructure developed to support a research reactor can be later extended to support a full nuclear power programme if the Member State so chooses. Conversely, infrastructure developed in support of a nuclear power programme will satisfy most of the needs of a research reactor.

In general, the smaller scale of the typical research reactor project requires infrastructure of the same scope, but to a lesser extent than would be the case for a nuclear power programme. Thus, a graded approach can be used in which the nuclear infrastructure elements are tailored to the needs of the research reactor project. Through appropriate consideration of all of the key issues, the infrastructure implementation for the research reactor project can be simplified whilst maintaining the required high standards of safety and security.

However, a research reactor can present unique challenges that are not encountered with NPPs, as discussed in Section 2.2. These issues should be specifically addressed.

2.2. KEY DIFFERENCES IN THE INFRASTRUCTURE ELEMENTS BETWEEN RESEARCH REACTORS AND NUCLEAR POWER PLANTS

There are differences between research reactors and NPPs that affect the development and implementation of the relevant supporting infrastructure. Although the smaller scale of the research reactor simplifies many issues, other aspects of the research reactor specification, funding and operation are more in fact more challenging and make the planning for a research reactor project particularly complex. Examples of these key differences are discussed below.

2.2.1. Stakeholder base and mission

Unlike nuclear power plants that exist predominately for the production of electrical power, research reactors address the needs of a diverse community of stakeholders, customers, policy makers, and other stakeholders (collectively referred to as ‘stakeholders’ below). The needs of these stakeholders are not only diverse, but also they change over time. Thoroughly and accurately defining the stakeholder community and detailing their specific needs and expectations is of fundamental importance to a new research reactor project.

2.2.2. Funding for operations, decommissioning and radioactive waste management

Commercial NPPs generate considerable revenues that pay for reactor operations and maintenance, and are the source of funds for their eventual decommissioning. This is not the case for research reactors. Attainable commercial revenues for research reactors are rarely more than a small fraction of the overall reactor operating costs. The balance of the operating costs, the costs of spent fuel and radioactive waste management and the reactor decommissioning funds will need to be provided from institute or governmental budgets.

The reactor may have an operating lifetime of several decades with decommissioning and spent fuel costs that extend well beyond that time. The planning and justification of the research reactor should consider that this funding commitment will bind successive governmental and institute administrations.

2.2.3. Organizational structure

The organizational structure of many research reactors must balance the conflicting needs of scientific research, technical services and commercial reactor utilization. In addition, the research reactor must balance user and funder priorities, which are not always well aligned. For example, a research reactor that is supported financially and administratively from the National Academy of Science, or equivalent, may find it difficult to offer effective services or products to industry or the nuclear power sector. Conversely, a reactor that is primarily funded by the nuclear power sector may find it difficult to maintain a significant capability in basic, rather than applied scientific research.

To ensure that all stakeholders are adequately serviced, and that the reactor will not face undue future budget pressures, these organizational challenges should be considered at the planning stage.

2.2.4. Waste management costs

Although the amount of radioactive waste generated by a research reactor is small compared to those from an NPP, the costs of management of spent fuel and other radioactive waste can be a very significant fraction of the total operations budget for a research reactor. This is particularly true in the absence of a national nuclear power programme able to carry the overhead costs of the necessary facilities. The eventual disposal of spent fuel or radioactive wastes may require the construction of repository facilities that are significantly more expensive that the reactor itself.

These issues must be addressed in the justification for the reactor. It is not sufficient that capital and operating funds are available for the reactor itself, but appropriate budgets must be identified for the spent fuel and the radioactive wastes that will be generated by the reactor.

2.2.5. Accessibility and site security

The research reactor must balance the overarching need to provide safe and secure operations with a high degree of facility access for users. This is significantly different from the case of an NPP, which has tightly restricted access to anyone other than a small, highly-trained and carefully selected operations staff.

This balance between secure operations and scientific access can be addressed in the reactor design, for example, by segregating reactor operations from the neutron beam line facilities [6].

However, the number of people able to come into contact with ionizing radiation and the manner in which this may happen is proportionately higher for the research reactor, and an issue requiring specific management and regulatory attention.

2.2.6. Nuclear material security

The nuclear fuel for research reactors typically contains a higher proportion of fissile isotopes than NPP fuel, and the individual fuel assemblies are smaller and lighter. This raises specific issues with regard to the safe management and security of the fuel that are not encountered at NPPs. The safety, safeguards, and security infrastructure, including software issues such as staff training and culture must be developed appropriately.

2.2.7. International cooperation

NPPs are typically constructed to meet national requirements for energy, and have tightly restricted access to personnel other than the operations and maintenance staff. In contrast, research reactors are likely to benefit from international cooperation in different ways, including:

- — Regional or international cooperation to obtain more robust reactor utilization and support, or to develop regional services and expertise;
- — Access of regional or international scientists and users to the facility, including to areas requiring secure access or presenting ionizing radiation hazards.

These issues should be addressed early in the planning for the research reactor, because they are likely to impact the specification and design of the research reactor.

In common with NPPs, research reactors may need to purchase fuel from international vendors, and may rely on contracts with international organizations for the processing and management of spent fuel. These issues may require the support of intergovernmental agreements to ensure their satisfactory and reliable resolution, which should be taken into account in the research reactor justification.

2.3. THE GRADED APPROACH

Research reactors are used for special and varied purposes including research, education and training, radioisotope production, non-destructive testing, materials research and development, support for the development of new generation nuclear power reactors, and other applications. These purposes call for different design features and different operation regimes. The design and operating characteristics of research reactors may vary significantly to accommodate the use of different experimental devices that can affect the reactors' performance. In addition, the need for flexibility in their use requires a different approach to achieving and managing safety and security. A 'risk informed analysis' of the characteristics, uses and associated facilities of the research reactor influence the scale of the required infrastructure.

The factors to be considered in deciding whether certain requirements established here may be lessened in applying a graded approach include:

- — The reactor power;
- — The source term, including fission product inventory, which depends on the reactor power and operating regime;
- — The amount and enrichment of fissionable material;
- — Fuel elements, high pressure systems, heating systems and the storage of flammables, which may affect the safety of the reactor;
- — The type of fuel elements;
- — The type and mass of the moderator, reflector and coolant;
- — The amount of reactivity that can be introduced and its rate of introduction, reactivity control, and inherent and additional safety features;
- — The quality of the containment structure or other means of confinement;
- — The utilization of the reactor (experimental devices, beam ports, irradiation loops/rigs, reactor physics experiments/tests);
- — Site examination/selection;
- — Proximity of population groups.

The above issues should be formally captured in the research reactor safety analysis report (SAR) which should guide the application of the graded approach.

2.4. THE INFRASTRUCTURE MILESTONES

The development of infrastructure to support a research reactor can be split into three sequential phases, each culminating in an 'infrastructure milestone'. The infrastructure milestone is a set of conditions that demonstrates that the preceding phase has been successfully completed. The milestone does not have a specific time schedule; the duration of each phase will depend upon the degree of commitment and resources applied by the Member State.

The three programme phases of development and their corresponding milestones are described in Table 1 and shown schematically in Fig.1.

There are three major organizational entities typically involved in the development of a research reactor project: the prospective research reactor operating organization, the government, and the regulatory body[1]. Each has specific roles to play with responsibilities changing as the project advances.

The operating organization for a research reactor may take many forms, including a state owned institute or laboratory, a commercial company, or a university. The operating organization may be the owner of the research reactor, or it may operate the reactor on behalf of the owner(s). Ownership and operation are, of course, more or less related to the goals set for the research reactor. The separation of the owner and operator roles may facilitate stakeholders to participate as reactor owners, and enables international ownership of a regional facility [7].

TABLE 1. INFRASTRUCTURE DEVELOPMENT PHASES AND MILESTONES

	Phase	Description	Milestone
(1)	Pre-project	Justification of the research reactor and considerations before a decision to launch a research reactor project is taken.	Ready to make a knowledgeable commitment to a research reactor project.
(2)	Project formulation	Preparatory work for the construction of a research reactor after a policy decision has been taken.	Ready to invite bids for the research reactor.
(3)	Implementation	Activities to design and construct a research reactor.	Ready to commission and operate the research reactor.

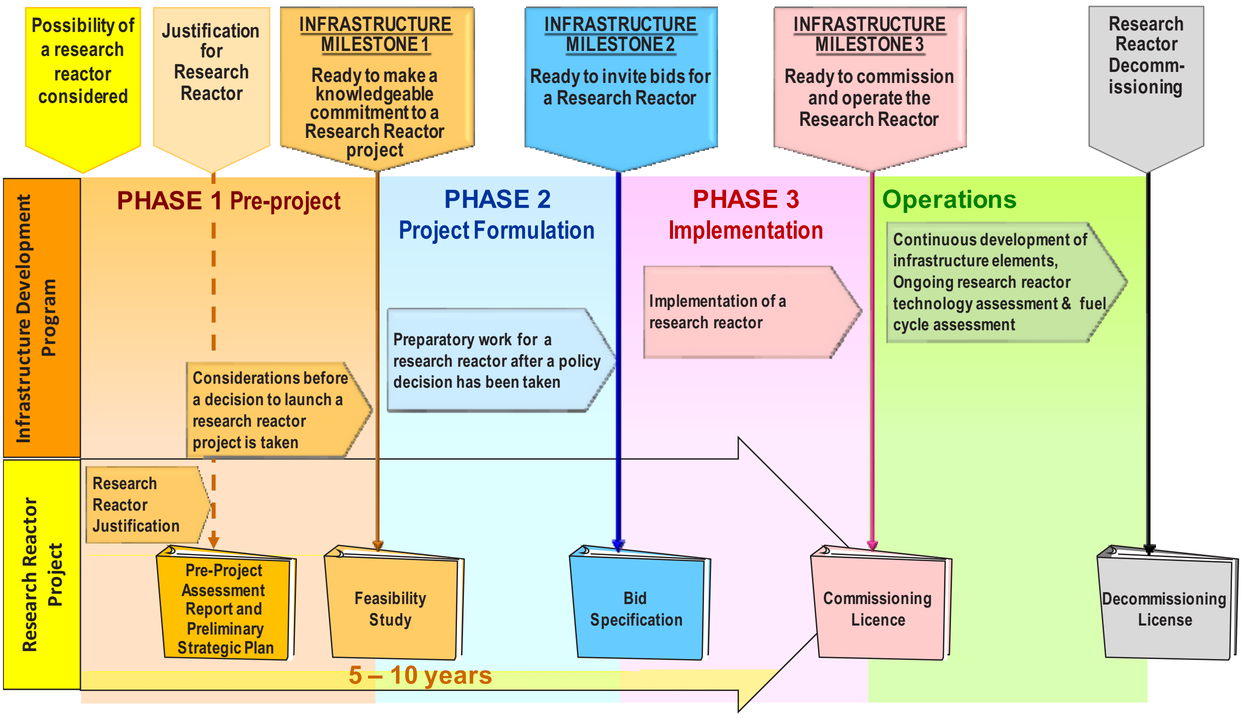

FIG. 1. Research reactor project and infrastructure development programme.

[1] The term regulatory body is used generically in this publication to mean the competent authorities for both safety and nuclear security, recognizing that these issues may be covered by two different competent authorities in practice.

The regulatory body may exist within the government, but must be effectively independent from the operating organization and from the other agencies responsible for developing the research reactor project.

As discussed in Section 3.2, an Assessment Marketing and Project Team (AMPT) should be formed to study, develop and promote the research reactor project. This team may be organized at the institute/reactor operator level, or it may be created as a governmental body. Its role is to build the justification for the reactor, develop a specification for it, and recommend to the government actions that should be taken to reinforce or implement the nuclear infrastructure and policy or intergovernmental issues that should be addressed.

In turn, the government should authorize a Research Reactor Project Implementing Commission (RRPIC) to review and accept, as appropriate, those recommendations and ensure that the necessary infrastructure and policies are in place prior to the construction of the reactor. Figure 2 shows the relationship between the AMPT and the RRPIC schematically.

For a first research reactor in the absence of a nuclear power programme, this RRPIC can be formed by representatives of the appropriate ministries. For subsequent research reactors, or if a nuclear power programme already exists, the function of the RRPIC will be assumed by the competent nuclear authority or regulator.

The scope of activities of the AMPT and RRPIC may be organized in different ways as long as all issues and activities are included[2]. For example, the AMPT and the RRPIC may be two separate bodies, or a single body, depending on where and how the initial momentum for the research reactor project begins, and the extent of existing nuclear infrastructure in the country. In the case of a first research reactor project that is initiated by the government as a national project, it is likely that RRPIC would assume both functions. In the case of a research reactor project that is initiated at the institute or reactor operator level and then presented to the government, or its appointed agency, for approval, these organizations will be separate.

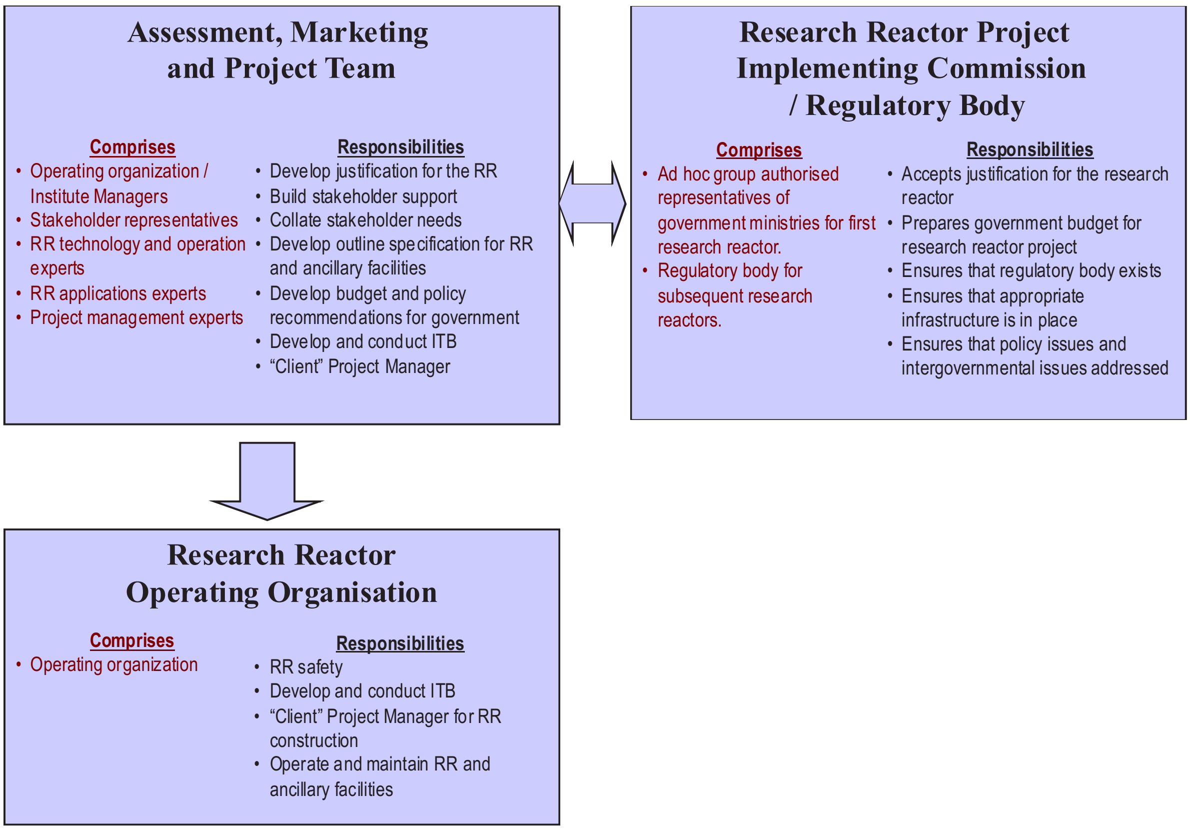

FIG. 2. Roles and relationships of the AMPT and the RRPIA.

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[2] A previous IAEA publication (IAEA–TECDOC–1513, Basic Infrastructure for a Nuclear Power Project) discussed a broadly analogous, government-appointed Nuclear Power Implementation Agency (NPIA), which performs the role of both the AMPT and the RRPIC.

For each milestone, there are nineteen issues that need to be considered, as shown schematically in Table 2. It should be noted that most of the issues indicated in the table also have safety components, as well as nuclear security considerations, as discussed in Section 3. The provisions of the Code of Conduct on the Safety of Research Reactors should be integrated into the programme from the earliest stages by making full use of the IAEA Safety Standards.

The order of the issues does not indicate importance or hierarchy. Each issue is important and requires careful consideration. From different perspectives the different issues have different weight. For example, from a legal standpoint the legal framework is the most important issue. From a safety perspective the regulatory framework and nuclear safety predominate. From an economical point of view the decision making under the national framework and the funding and financing issues are likely to be the prime considerations. Similar comments could apply for those responsible for safeguards or security or other areas. The difference in weight clearly depends upon the perspective of the reader. Different organizations will need to consider which of these issues relate to them and which therefore, they should address with the highest priority. The three major organizations mentioned earlier; i.e. government, operating organization and regulatory body; need to ensure awareness of all the issues.

The nineteen infrastructure milestone issues are organized differently from twenty safety infrastructure elements established by the INSAG-22 [8] publication, and according to the structure of the IAEA Safety Standards. All of the twenty elements from INSAG-22 are addressed at appropriate points within the nineteen milestone issues. Table 3 provides the cross reference between the milestone issues and the IAEA Safety Standards. The INSAG-22 elements transport safety, and the interface between safety and security are not separately identified within the milestones, but are important to, and are addressed within, several milestone issues. Table 4 shows the same information as Table 3 but referenced to the INSAG-22 elements.

TABLE 2. INFRASTRUCTURE ISSUES AND MILESTONES

Issues	Milestone 1	Milestone 2	Milestone 3
National position	CONDITIONS	CONDITIONS	CONDITIONS
Nuclear safety			
Management			
Funding and financing			
Legislative framework			
Safeguards			
Regulatory framework			
Radiation protection			
Research reactor utilization			
Human resources development			
Stakeholder involvement			
Site survey, site selection and evaluation			
Environmental protection			
Emergency planning			
Nuclear security			
Nuclear fuel management			
Radioactive waste			
Industrial involvement			
Procurement			

Sections 4–6 present a detailed discussion of the conditions corresponding to each of the nineteen issues that are necessary to meet the infrastructure milestones. These are summarized in the tables in the appendix.

TABLE 3. INFRASTRUCTURE MILESTONE ISSUES AND RELATED INSAG-22 ELEMENTS

Milestone issues	Main supporting current IAEA Safety Standards	Support in long term IAEA Safety Standards structure	Relevant elements from INSAG-22
National position	GS-R-1	GSR-Part 1	National policy and strategy; Global nuclear safety regime
Nuclear safety	NS-R-4, GSR-Part 4, TS-R-1	SSR 3	Global nuclear safety regime; Safety assessment; Design safety; Preparation for commissioning; Transport safety
Management	GS-R-3, NS-R-4	GSR-Part2, SSR 3	Leadership and management of safety; Transparency and openness; External support organizations and contractors
Funding and financing	GS-R-1, NS-R-4	GSR-Part 1	Funding and financing
Legislative Framework	GS-R-1, NS-R-4, TS-R-1	GSR-Part 1, SSR 3	Legal framework
Regulatory framework	GS-R-1, NS-R-4, TS-R-1	GSR-Part 1, SSR 3	Regulatory framework
Safeguards	Not covered by safety standards		
Radiation protection	NS-R-4	GSR-Part 3	Radiation protection
Application, utilization and facilities	NS-R-4	SSR 3	Not applicable
Human resources development	NS-R-4	SSR-3	Human resources development
Stakeholder involvement	GS-R-3	GSR-Part 2	Leadership and management of safety; Transparency and openness
Site survey, site selection and evaluation	NS-R-3, NS-R-4	SSR-1	Site survey, site selection and evaluation
Environmental protection	GSR-Part5	SSR-3, GSR-Part 5	Radiation protection; Safety of radioactive waste, spent fuel management and decommissioning; Transport safety;
Emergency preparedness and response	GS-R-2	SSR-3, GSR-Part 7	Emergency preparedness and response
Nuclear security	NS-R-4	SSR-3	Interfaces with nuclear security
Nuclear fuel management	NS-R-4, TS-R-1	SSR-3, SSR-5	Safety of radioactive waste, spent fuel management and decommissioning;
Radioactive waste	NS-R-4, WS-R-2	SSR-3, SSR-5, GSR-Part 5	Safety of radioactive waste, spent fuel management and decommissioning;
Industrial involvement			External support organizations and contractors
Procurement	GS-R-3, NS-R-4	GSR-Part 2, SSR 3	Funding and financing; External support organizations and contractors

GSR: General safety requirements; SSR: Specific safety requirements

TABLE 4. INSAG-22 ELEMENTS AND RELATED MILESTONE ISSUES

Relevant elements from INSAG-22	Milestone issues	Main supporting current IAEA Safety Standards	Support in long term IAEA Safety Standards structure
National policy and strategy	National position	GS-R-1	GSR Part 1
Global nuclear safety regime	National position/nuclear safety	GS-R-1, NS-R-4	GSR Part 1, SSR 3
Legal framework	Legal framework		
Regulatory framework	Regulatory framework		
Transparency and openness	Management/ stakeholders involvement	GS-R-1	GSR Part 1
Funding and financing	Funding and financing, procurement		
External support organization and contractors	Management/industrial involvement, procurement		
Leadership and management of safety	Management	GS-R-3, NS-R-4	GSR Part 2, SSR 3
Human resources development	Human resources development	GS-R-3, NS-R-4	GSR Part 2, SSR 3
Research for safety for regulatory process	Regulatory framework		
Radiation protection	Radiation protection	BSS, NS-R-4	GSR Part 3, SSR 3
Safety assessment	Nuclear safety	GSR Part 4, NS-R-4	GSR Part 4, SSR 3
Safety of radioactive waste, spent fuel management and decommissioning	Radioactive waste/ nuclear fuel cycle	GSR Part 5, NS-R-4	GSR Part 5, SSR 3
Emergency preparedness and response	Emergency planning	GS-R-2, NS-R-4	GSR Part 7, SSR 3
Operating organization	National position/management	NS-R-4	SSR 3
Site survey, site selection, and evaluation	Site and supporting facilities	NS-R-3, NS-R-4	SSR 1, SSR 3
Design safety	Nuclear safety/management	NS-R-4	SSR 3
Preparation for commissioning	Nuclear safety/management	NS-R-4	SSR 3
Transport safety	Nuclear safety/nuclear fuel cycle/ environmental protection	TS-R-1	SSR 6
Interfaces with nuclear security	Security and physical protection/ nuclear safety	—	—

2.5. NATIONAL POSITION

Strong government support is vital to the successful implementation of a first research reactor project and the intention to develop such a programme should be announced and supported at the most senior level of government. Government leadership and funding is necessary to ensure that the appropriate infrastructure is put in place, and intergovernmental agreements negotiated. Because a research reactor is unlikely to self generate funds to cover long term waste liabilities, the government needs to understand and make provisions for including spent fuel management and eventual facility decommissioning, that will be required throughout the research reactor life cycle.

2.6. NUCLEAR SAFETY

The issue of nuclear safety permeates all of the issues associated with nuclear infrastructure and the research reactor project. It requires the commitment of all people and organizations involved. These include the operating organization, users of the facility, the regulatory body, suppliers, other organizations, and the government.

Embarking on a research reactor project implies that a Member State becomes a partner in the Global Nuclear Safety Regime dedicated to maintaining nuclear safety worldwide, with the opportunity to participate in the international cooperation network for nuclear safety. It is essential that nuclear reactor programmes are implemented consistently with the IAEA Fundamental Safety Principles and relevant IAEA Safety Standards. This includes also subscribing to intergovernmental instruments on safety (e.g. legally binding Conventions and the Code of Conduct on the Safety of Research Reactors), applying the IAEA Safety Standards, and participating in various efforts to share knowledge and experience through information networks and the activities of the relevant international and regional organizations.

Past experience has demonstrated that reliance on engineered safety systems is, by itself, insufficient to ensure nuclear safety. The important lesson is that safe and secure operations can only be ensured if there is an infrastructure in place to ensure that the specific requirements of nuclear technology are recognized and that appropriate conditions are established to deal with them safely.

While the legislative and regulatory regimes are of utmost importance for a safe research reactor project, they alone will not provide the highest level of safety. Experience has shown that the development of a good safety culture within all organizations involved in a research reactor project will not only elevate the level of safety achieved, but will also result in a more efficient and credible programme. Recognizing the need to establish a safety culture requires that all individuals involved in the programme accept a personal responsibility for safety and perform all their activities with this thought in mind. This is a key activity that needs to be demonstrated in order to achieve all the milestones.

The IAEA Safety Standards provide the safety requirements (and guidance to meet these requirements) that are needed to effectively apply the provisions of the Code of Conduct on the Safety of Research Reactors. These safety requirements should be applied from the start of the research reactor project. The level of application of these safety requirements should be increased progressively with the different phases of the programme as shown schematically in Fig. 3.

The experience of many countries shows that the following are of particular safety importance for a research reactor project:

- ***Operator capabilities and skills***. The operating organization of the research reactor has the prime responsibility on safety. This means, for example, that the operator must have the organizational and technical ability to review the reactor design, safety assessments and operation plans;
- ***Management system***. The management system for nuclear facilities and activities must deal in a coherent manner with safety, health, environmental, security, quality and economic requirements, throughout facilities' life cycle in normal, transient and emergency situations;
- ***Safety culture.*** The safety culture of all involved organizations should be routinely assessed and maintained over the lifetime of the plant;
- ***Legal framework.*** The legal framework should place the prime responsibility for safety on the operating organization;
- ***Regulator independence, competence, and authority***. The regulator needs competent, knowledgeable and authoritative regulatory staff with appropriate access and support;
- ***Technical competence***. Availabilty of manpower with the diverse skills needed for the operation, regulation, and maintenance of the research reactor project is key;
- ***Financial stability***. Research reactors are not self-financing, such that special attention to the funding mechanisms for the life cycle of the facility is required at the outset of the project;
- ***Emergency preparedness***. Every country that operates a research reactor must be prepared for the possibility that its efforts to ensure safe operations might fail and that a nuclear emergency could arise;
- ***International connectivity.*** It is important to make full use of the global support capabilities.

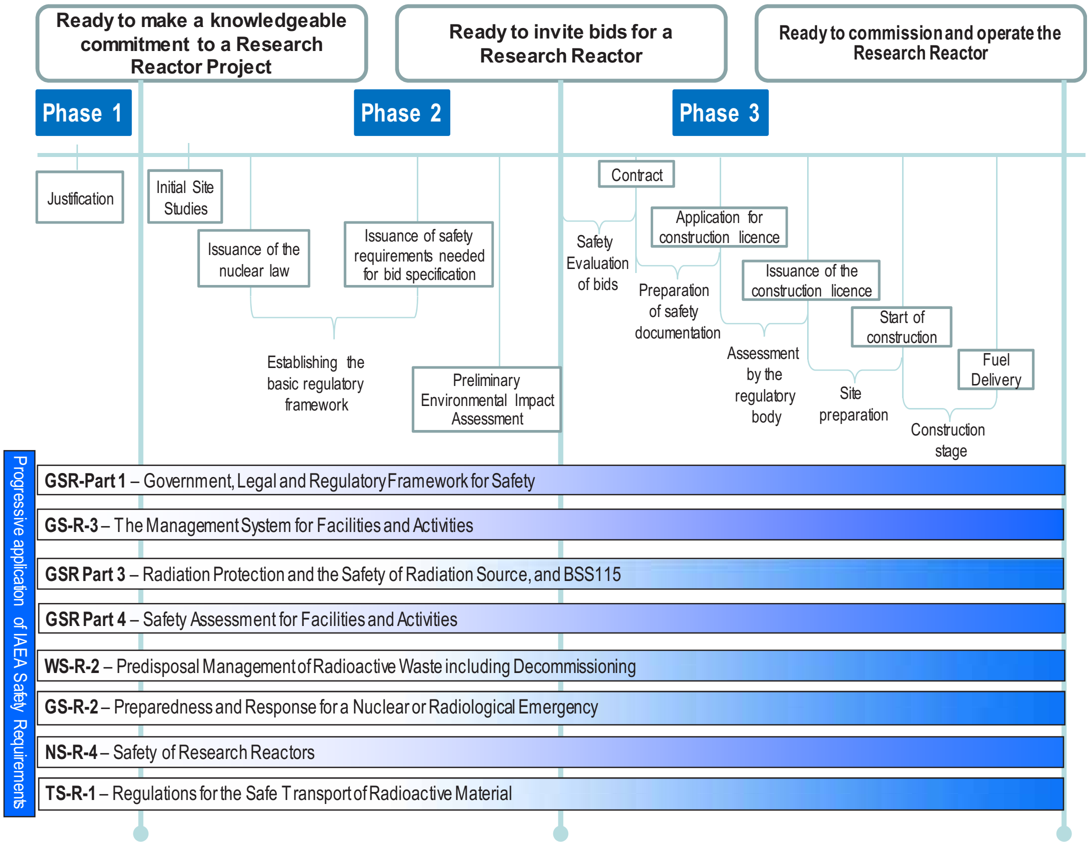

FIG. 3. Progressive application of the IAEA Safety Standards.

2.7. MANAGEMENT

The management of a research reactor project is a demanding undertaking. A highly competent management is vital to the success at all project stages. The roles and responsibilities of management will change over time as the project progresses from the initial stages through construction and operation and then to decommissioning. Efficient communication and interaction between the different organizations involved in the project (in particular between the regulatory body, operating organization, and reactor designer or supplier) is vital for its effective, safe, and secure implementation.

The initial and final phases of the project require project management expertise and methodologies. This includes Risk Informed Analyses to anticipate and pre-empt or mitigate difficulties and failures. Risk Informed Analysis is also fundamental to the ‘Graded Approach’ to infrastructure development discussed in Section 2.3.

The organization structure of the owning and operating organizations is of fundamental importance to the long term viability of the reactor. Experience has shown that research reactors that lack good interactions with their stakeholders, or that cannot adapt their mission as circumstances change, may become underutilized and underfunded. The IAEA report on the Status of Nuclear Research and Development Institutes in Central and Eastern Europe [3] confirmed the importance of the fit between the reactor mission, the organization structure, reporting relationships, key performance indicators, and staff incentives, if healthy funding and utilization are to be maintained.

Management of regional research reactor facilities presents an additional challenge. Research reactors can benefit from the scientific, technical and financial support of the international community. This can drive utilization, help to share costs, and avoid wasteful duplication of R&D investments and fragmentation of scientific effort. A research reactor that is designated as a regional facility will have additional opportunities for funding and utilization, and new opportunities for the personal professional achievement of the reactor scientists and staff.

Developing a research reactor as a facility with international access or international equity participation is a complex task, however. The needs of potential international users and supporters including the need for access to the reactor's facilities must be balanced with the national responsibilities for operational safety, safeguards, and security.

2.8. FUNDING AND FINANCING

Funding and financing[3] of a research reactor project must address two parallel issues: the research reactor and its ancillary facilities; and the creation or extension of the supporting nuclear infrastructure.

It should be recognized that the research reactor represents a significant capital commitment, ranging from several million dollars for a small research reactor to hundreds of millions of dollars for a large facility. There is also a large ongoing cost associated with operation, maintenance and decommissioning of the research reactor that is likely to extend many decades after reactor closure. The major cost components include all operations and maintenance costs, provisions for decommissioning and waste management, physical security, insurance, and legal issues.

In addition, the funding and financing requirements for an adequate peaceful nuclear infrastructure may be significantly more than those of the research reactor itself. Governmental funding will be needed to create the regulatory bodies, enhance education and training facilities, and construct and operate long term radioactive waste management facilities.

As previously noted, research reactors are unlikely to become financially self-supporting, and will not generate revenues during operations that can cover the costs of long term spent fuel management or eventual facility decommissioning. This stands in contrast to commercial nuclear facilities or nuclear power reactors for which the cost of such liabilities are recovered from operational revenues. Thus the funds or the funding mechanisms should be identified at the start of the project both to ensure financial stability during operations, and to fully provide for facility decommissioning and spent fuel management. For most research reactors, this is the responsibility of the government. If funding mechanisms are not established at the project outset the research reactor may be impacted by the varying financial priorities of future governments.

2.9. LEGISLATIVE FRAMEWORK

The legal framework establishes the duties and responsibilities of the various organizations necessary for a successful research reactor project. It includes both the legislative framework and the regulatory framework. Because of the importance of each of these components, the legislative and regulatory frameworks are discussed in separate parts of this publication.

Nuclear facilities cannot be operated in isolation. For a research reactor project to be properly implemented, the national legislation should cover, in a comprehensive manner, all aspects of nuclear law; i.e. nuclear safety, security, safeguards and liability for nuclear damage. The Legislation should also implement, or authorize implementation of any international instruments to which the government is a party. Table 5 provides a list of the key international instruments that should be considered.While the legislation may address both the enabling and regulatory aspects of a peaceful nuclear programme, general experience suggests that safety, safeguards, security, and credibility are best served by institutionally separating the two functions. Therefore, the legislation should provide for an effective separation between the functions of the regulatory body, and those of any other bodies or organizations concerned with the promotion or utilization of nuclear technology.

Any Member State considering a research reactor project should put in place a national infrastructure for radiation, waste, and transport safety and security that is in compliance with international standards and covers all current activities, practices and facilities in that Member State. In overseeing the development of the necessary

[3] In general, the term funding refers to items that are the fiscal responsibility of a government in establishing a peaceful nuclear programme; e.g. ensuring the necessary resources for the regulatory body. The term financing refers to items that are the fiscal responsibility of the operator (whether it is the government or a private utility).

legislative framework for a research reactor project, the RRPIC should make use of the experience and knowledge gained in developing and implementing the existing national safety infrastructure.

Nuclear law is a specialized field. Professional input from experts is highly desirable to completely understand and correctly formulate the appropriate legislation. However, the legislation should be consistent with national legal and political traditions, institutions, economic circumstances, level of technological development and cultural values. The legislation needs to be in place early in the research reactor project development effort.

2.10. REGULATORY FRAMEWORK

Crucial to the long term success of a research reactor project is the existence of an independent and competent regulatory body. To be effective, the regulatory body needs adequate authority, independence, financial resources, and technically competent staff. The confidence of the public and the international community depends on an effective regulatory body. The essential need for a competent and effective regulatory body should be understood and given high priority by the RRPIC, in close consultation with the existing regulatory body for the control of radiation sources. The development of competent human and physical resources for the expanded, or new, regulatory body is as important as it is for the operating organization. The technical training, knowledge and capabilities of the regulator should be adequate for competent interaction with the operating, supplier organizations and consultants.

Experience has shown that safety, safeguards, security, and credibility are best served by a complete separation of the regulatory body from the promotional and implementing organizations and the political process. While not all governments began their peaceful nuclear programmes with this provision, virtually all are adopting this approach.

The regulatory framework should be adequate for the size of the planned research reactor. Member States embarking on a research reactor project should consider the efficiencies of building on the national infrastructure already in place for radiation, waste and transport safety and security. Expanding the existing regulatory body to take on the role as regulator for a research reactor would seem to offer significant advantages in terms of utilizing resources (facilities and human) that are likely to be limited in many Member States.

Establishing an effective regulatory framework includes development of a regulatory approach that is consistent with the established laws, and compatible with the existing regulatory framework, if it exists, for radiation protection, waste and transport safety and security. The government should consider various alternative regulatory approaches. The regulatory approach chosen will have a major influence on the national resources needed by the regulatory body, and the need for external support to the regulatory body. Therefore, selection of a regulatory approach is an important element within the regulatory framework. Some governments have begun the process by adopting the regulations of the governments supplying the first research reactor. This is an acceptable approach, provided it is consistent with the established laws. However, over time and as the staffing and experience of the regulatory body increases, it is desirable to adapt the regulations to local and cultural conditions.

TABLE 5. RELEVANT INTERNATIONAL INSTRUMENTS

- Comprehensive Safeguards Agreement (INFCIRC/153 Corr.)
- Additional Protocol pursuant to INFCIRC/540 (Corr.)
- 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)
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive waste Management , reproduced in document INFCIRC/546
- Convention on the Physical Protection of Nuclear Material (INFCIR/274) and Amendment
- Vienna Convention on Civil Liability for Nuclear Damage (INFCIRC/500)
- Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention, reproduced in document INFCIRC/402
- Protocol to Amend the 1963 Vienna Convention on Civil Liability for Nuclear Damage
- Convention on Supplementary Compensation for Nuclear Damage
- Revised Supplementary Agreement concerning the provision of Technical Assistance by the IAEA
- Code of Conduct on the Safety of Research Reactors

2.11. SAFEGUARDS

Reference is made to international treaties and agreements, such as the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), wherein States Party to the NPT undertake to accept safeguards. These safeguards would be set forth in an agreement to be negotiated and concluded with the IAEA for the exclusive purpose of verification of the fulfilment of obligations assumed under such treaties with a view to preventing diversion of nuclear research reactor products or fuel from peaceful uses to nuclear weapons or other nuclear explosive devices. A Member State embarking on research reactor project would be expected to have in place a national infrastructure for safeguards, a State System of Accounting for and Control of (SSAC) nuclear material that is in compliance with international standards and covers all current activities, practices and facilities in that Member State.

In this regard, a Member State considering a research reactor project should have a clear understanding of, and demonstrate a commitment to, its international non-proliferation obligations as well as of its safeguards agreement with the IAEA. This knowledge will provide an understanding of the safeguards commitments inherent in the use of nuclear technology, and the infrastructure will give support to the State's implementation of an effective strategy for meeting its safeguards obligations.

2.12. RADIATION PROTECTION

Laws, regulations and monitoring programmes are necessary to ensure worker, public and environmental protection in all circumstances. Most countries already have provisions for radiation protection because medical, industrial and research applications of ionizing radiation are common worldwide. A Member State considering a research reactor project would be expected to have in place a national infrastructure for radiation, waste and transport safety and security that is in compliance with international standards and covers all current activities, practices and facilities in that Member State.

The radiation protection aspects of a research reactor project require special consideration. However, the existing infrastructure should continue to be used for radiation protection with appropriate expansion to cater for the special needs of the research reactor project.

2.13. RESEARCH REACTOR UTILIZATION

It is very important for the sustainability of the research reactor that it and its ancillary facilities are adequately utilized. Underutilized facilities often struggle to maintain adequate funding levels, so the utilization of the facility has a direct influence on facility safety, security, and performance. It is not a necessary condition that a research reactor has high availability to be adequately utilized.

In order to maximise research reactor utilization it is important that the goals of the research reactor programme are defined early in the planning phase, as discussed in Section 3. Interaction and engagement with the international community will assist with this definition. It is also important that the stakeholders are engaged in the planning phase, as ultimately they will dictate the specific uses of the facility.

A strategic plan should be developed for the research reactor project at the outset, to help avoid problems with possible underutilization of the research reactor as it ages. The strategic plan should be updated periodically in consultation with the stakeholders and, if appropriate, with external experts. The periodicity of review is a matter for the management of the research reactor, but this would not normally be more than 5 years.

2.14. HUMAN RESOURCE DEVELOPMENT

The safe and secure implementation of a research reactor project requires the access to, or development of, sufficient human resources. The knowledge and skills necessary to specify, purchase, construct, license, operate, maintain and decommission a research reactor in compliance with regulations are spread across most scientific and engineering disciplines. The expertise, experience and skill of the operating staff are vital to the successful and safe utilization of the research reactor and its in-core and peripheral facilities.

As with other nuclear facilities, research reactors require additional knowledge and increased attention to detail to ensure operational safety, security, and radiation protection. Thus, specific expertise in reactor physics, thermal-hydraulics, radiation shielding and nuclear materials science for reactor operation and fuel cycle management is crucial.

Prior to operation of the research reactor, the personnel must already be trained and have experience in existing research reactor facilities.

In addition to the technical skills, a good safety and nuclear security culture is necessary. This instils a personal responsibility for safety and security for all individuals involved in the programme. INSAG-15 Key Practical Issues in Strengthening Safety Culture [9] provides an overview of the requirements for developing and maintaining a good safety culture in nuclear organizations.

In addition to fundamental scientific and technical education, nuclear workers typically receive extensive specialized training in safety, security, and radiation protection and in the design and operation of the specific technology chosen for deployment. Specialized training can be obtained from the vendors and suppliers of the research reactor and its systems and components. However, it is desirable and recommended for a nation to develop its own educational and training capabilities to better ensure the long term availability of human resources and provide opportunities for its citizens. Member States can also request assistance from the IAEA in developing itsf human resources. While the development of human resources requires investment, this investment brings overall benefit to the economic development of the nation.

For a country developing a research reactor, a first step toward a nuclear power programme would be to consider the staffing needs and the relationship of the newly established operating organization of the research reactor with the operating organization of the future NPP, including the difference in nature of both organizations. The objective is to capitalize effectively on the experience obtained during the establishment of the new research reactor, ensuring knowledge in the NPP programme.

A Member State should take into account the international best practices in human resource development. To achieve this, the development of international collaborations can be beneficial. These collaborations may include IAEA fellowships, developing networks and partnerships, and establishing connections to nuclear education institutions. Once the regulator and operating organization are established, each one should develop and maintain international and regional collaborations. During Phase 2 it is important for the operating organization to establish a close link to the design authority, and use that link to establish technology and knowledge transfer programmes so that design information is transmitted effectively to the operating organization.

2.15. STAKEHOLDER INVOLVEMENT

The stakeholders are those who have a specific interest in the research reactor project, or may be affected by it; including the general public. Stakeholder involvement in the research reactor project is important as it helps to shape both the specification and the eventual utilization of the research reactor. The comments and the pressure from the stakeholders will contribute to the correct management of the project, because the project objective is the service to be provided by the reactor, and not the construction of the reactor in itself.

Stakeholders include both internal, those involved in the decision making processes, and external, those affected by the project outcome (output).

The potential users of the research reactor and the customers of its products and services can contribute significantly to the robustness and the credibility of the project in each phase by advocating the programme towards all the country stakeholders and abroad. Their involvement in this user community also provides a continuous monitoring and assessment of the programme efficiency in terms of flexibility, quality of the service, and cost effectiveness of the proposed facilities, and can contribute substantially to safety. Continuous stakeholder involvement in the strategic management of the reactor and its ancillary facilities, for example, through representation on the strategic and policy organs of the operating organization, can help to underpin long term sustainability.

Involvement of the general public can best be achieved through an open and honest dialogue with the proponents of the research reactor (e.g. government and the operating organization) and other stakeholders, and by emphasizing the contribution of the research reactor to issues such as nuclear medicine, industrial competiton and agricultural output that are of general importance.

Since, in some cases, a nuclear research reactor has the potential for causing concern across national boundaries, a dialogue with neighbouring countries may be appropriate.

2.16. SITE SURVEY, SITE SELECTION AND EVALUATION

Site selection and evaluation is a crucial part of a research reactor project and can significantly affect costs and public acceptance. Site surveys are necessary to determine the availability and suitability of potential sites. General surveys should initially categorize and rank potential sites in order of merit by a set of criteria reflective of national and cultural considerations, including the safety and nuclear security considerations (proximity of populated areas, neighbourhood agriculture or other field activities, etc.). As the research reactor project development progresses, sites should be narrowed to those most favourable and the final site selected for characterization for the bid specification. The selected site should be secured at an early time to ensure its availability and integrity.

It should be recognized that research reactors require supporting infrastructure, which includes, but is not necessarily limited to, waste management facilities, applications support and security zones, interim spent fuel storage, hot cells for radioisotope processing or post-irradiation analysis. The important elements of site study (IAEA site selection guide) and characterization are described in IAEA Safety Standards Nos NS-R-3 and NS-G.3.1- 3.6.

2.17. ENVIRONMENTAL PROTECTION

Environmental protection should receive careful attention when a research reactor project is contemplated. A specific consideration with any nuclear reactor operation is the release of gaseous and liquid radioactive effluents during normal operation.

Large releases of radiation are low probability events which are appropriately treated through the nuclear safety programme. Land use, water use and quality and other more conventional environmental impacts should also be considered. The overall impact will vary depending on potential requirements and hazards of the research reactor. The impact of the research reactor’s ancillary facilities should be considered as well.

2.18. EMERGENCY PLANNING

Research reactors are designed and operated with full attention to safety.The safety system design minimizes the probability of radioactive release from the installation. Despite all these precautions, there remains a risk that a failure or an accident gives rise to an emergency. Emergency response actions may be necessary to mitigate the consequences of released radioactive materials within installations and/or into the public domain. The appropriate branches of government and the regulatory body have to establish in advance and maintain (particularly with periodic exercises) arrangements for preparedness and response for a nuclear or radiation emergency at the scene, at local, regional and national levels and, where so agreed between States, at the international level.

The nature and extent of arrangements for emergency preparedness and response shall be commensurate with the potential magnitude and nature of the hazards associated with the research reactor. The scope and extent of these arrangements have to reflect:

- The likelihood and the possible consequences of events;
- The characteristics of the radiation risks;
- The nature and location of the installations and activities, particularly as regards to proximity of populations.

Emergency planning for protection of plant personnel, emergency workers and the public beyond the site boundary is a necessary element of overall plant safety and provides an additional level of defence in depth.

2.19. NUCLEAR SECURITY

Nuclear security requires the commitment by all elements of the national government, operating organization, regulatory body, suppliers and other organizations in the promotion and achievement of security in a research reactor project.

When embarking on a research reactor project, Member States should develop and maintain a nuclear security regime consistent with the IAEA Nuclear Security Fundamentals and other IAEA Nuclear Security Series guidance.

While the legislative and regulatory frameworks are of utmost importance for a successful research reactor project, they alone will not provide the highest level of security. The development of a security culture within all organizations involved in a research reactor project will elevate the level of security achieved, but will also result in a more efficient and credible programme.

The following highlight issues of particular security importance for a research reactor project:

— ***Operator skills and attitudes***. The operating organization of the research reactor has the prime responsibility for security. This means, for example, that the operator must have the organizational and technical ability to review the reactor security assessments and operation plans. The interface between security and safety should also be identified;
— ***Management system***. A management system for nuclear facilities and activities needs to be implemented, dealing in a coherent manner with safety, health, environmental, security, quality and economic requirements, throughout the lifetime of the facilities and for the entire duration of activities, in normal, transient and emergency situations;
— ***Security culture.*** Should be promoted, assessed and maintained over the lifetime of the plant;
— ***Legal framework.*** The legal framework should place the prime responsibility for safety on the operating organization;
— ***Regulatory independence, competence, and authority.*** Just as the operating organization needs to have experienced staff, there is a need for sophisticated, competent and knowledgeable regulatory staff with appropriate access and support;
— ***Technical competence***. A common theme of several of these elements is the need for manpower with the skills to undertake the operation, regulation, and maintenance of the entire research reactor project in a sustainable manner;
— ***Financial stability.*** To sustain security adequate financial support throughout and beyond the operating life of the plant is necessary;
— ***Contingency planning.*** Every country that initiates a research reactor project needs not only to take the steps to ensure secure operations but also to prepare for the possibility that its efforts might fail and that a nuclear security event could arise.

2.20. NUCLEAR FUEL MANAGEMENT

A thorough consideration of the fuel management strategy is essential from the earliest planning stages. The fuel cycle is usually thought of as two components: the front end to supply necessary fuel elements and the back end to manage spent fuel removed from the reactor.

Regarding the front end, a commitment to use low enriched uranium (LEU, i.e. less than 20% of ^{235}U) for the research reactor should be established from the very beginning of the project, as there are few if any suppliers of high enriched uranium (HEU, i.e. greater than 20% of ^{235}U), fuel elements that would support a new research reactor project that uses HEU.

Ideally, the long term strategy for fuel supply should be developed prior to reactor operation to ensure that adequate fuel supplies will be available as required. While the first core might be part of the contract for building the reactor, the operating organization will likely be responsible for purchasing any replacement fuel. The fuel elements are often fabricated by a third party organization, rather than the research reactor supplier. The reactor operator can benefit by observing the supplier’s procurement of the first core, to learn how fuel is purchased and what information must be exchanged with the fuel fabricator.

It is also recommended that the country use LEU instead of HEU targets for radioisotope production.

Regarding the back end, the operating organization has to plan three management phases from fuel elements unloading. The first phase addresses in-pool storage at the reactor facility as long as necessary for the fuel to cool to a level appropriate for further processing or storage. This must be operational from the very start of reactor operation at the reactor storage facility. The second phase considers the long term management of spent fuel, and includes extended wet or dry storage, fuel processing (if applicable). Wet storage technologies have been developed for very long storage of spent research reactor fuel, and may be appropriate depending on the fuel materials and design and space available. However, continuous monitoring is required to maintain water quality and fuel integrity. Dry storage techniques have a lower monitoring and maintenance requirement and may reduce the administration overhead compared to in-pool storage. The third phase is the final disposition. Increasingly, the existence of adequate financial and technological plans for storage and final disposal are set as licensing conditions for the new research reactor.

If is it planned to process spent fuel in another country prior to ultimate disposal, specific intergovernmental agreements may be required, and should be identified and negotiated at the start of the project.

The policy for this second phase has to be fixed and presented to stakeholders but implementation will be managed far beyond the start of operation.

2.21. RADIOACTIVE WASTE

The handling and disposal of radioactive waste is an essential issue associated with a research reactor. Radioactive waste needs to be managed in such a way as to avoid imposing undue legacy issues. That is, the generations that produce the waste have to seek and apply safe, practicable and environmental acceptable solutions for its long term management. Radioactive waste is generally treated in three levels: low, intermediate and high level. A research reactor typically produces only small quantities of high level waste in addition to the spent fuel which is addressed in Section 2.20. Nevertheless significant quantities of high level waste may be generated if irradiated uranium targets are used to produce ^{99}Mo for medical applications. Capabilities for low and intermediate level waste management exist in many countries in conjunction with medical, industrial and research applications, within the framework of the national infrastructure for radiation, transport and waste safety and nuclear security. Some countries have also developed disposal capacity for these wastes.

The additional volume and the different spectrum of radioactive isotopes associated with the research reactor operation need to be understood with respect to existing low and intermediate level disposal capabilities.

Programmes and technology for low and intermediate level waste minimization and processing have been developed and successfully implemented in many countries.

2.22. INDUSTRIAL INVOLVEMENT

Many structures, systems, components and services are required to construct and support the operation of a research reactor facility. Spare parts, consumable supplies, instrument repair and calibration services are among the many support needs. Some of these needs could be supplied by local industries. Supplying equipment and services to support a research reactor facility requires industrial organizations that comply with the codes and standards and operate under rigorous quality programmes.

2.23. PROCUREMENT

Procurement of equipment, services and consumables for a research reactor facility requires special technical competences. For example, larger research reactors usually have a fuel specialist with the expertise to inspect replacement fuel at the fabricator’s premises. Careful planning is required, as the procurement may involve long lead times and detailed acceptance testing according to special quality and environmental standards.

Much of the equipment associated with the research reactor can be provided by the research reactor supplier if desired. The design and quality standards should be included in the bid specification. If the Member State desires that some of the nuclear safety and security related equipment are purchased from national or local suppliers, or from other international suppliers, the operating organization must specify the quality requirements and verify that the supplier meets those requirements.

Another issue that should be considered is that the acquisition of a research reactor is expensive and in most cases will have a high media profile. The project will be keenly observed both within the Member State and internationally. For these reasons, Member States embarking on a research reactor project are recommended to apply rigorous oversight to the management of the procurement process, through the appointment of an experienced procurement manager, as well as an independent probity auditor to ensure that the project is demonstrably free from bribery, corruption and favouritism, and free of pre-conceived ideas regarding the quality and performance of the product being purchased.

3. RESEARCH REACTOR JUSTIFICATION

A research reactor project can take many forms. The type, size, power and cost of the research reactor designs and its ancillary facilities should be matched to the needs of the potential stakeholders and to the financial resources that are available. The ancillary facilities include such items as educational facilities, neutron beam lines and instrumentation, isotope preparation hot cells and chemical processing facilities, etc.

It is recommended that the ancillary facilities are always considered as an integral and essential part of the research reactor project. A research reactor cannot be utilized without the ancillary facilities. The quality and adequacy of the ancillary facilities therefore determine a large part the usefulness and effectiveness of the research reactor.

A research reactor may be constructed to meet the requirements of a single Member State, or to serve as a regional or international centre of excellence; helping to meet the needs of both the initiating Member State and its neighbours or collaborators. Developing the case for a regional facility is more difficult and complex, but is potentially highly beneficial, providing higher utilization, additional human and financial resources, and helping to elevate the scientific stature of the host Member State. Regional cooperation can cross-fertilize experience between the collaborating States, help to adopt best practices, and to get and maintain high standards in expertise, in experimental tools and facilities.

This section discusses the conduct of the stakeholder needs assessment, development of the initial strategic plan for the research reactor, and the adaptation of the research reactor specification to meet the identified needs. Support for the research reactor justification can come from the IAEA in the form of specific IAEA publications, expert meetings, TC projects, and information from other research reactor projects. Relevant information may also be available from research reactor vendors and other countries that have recently made the decision to purchase a research reactor.

3.1. RESEARCH REACTOR PRE-PROJECT ASSESSMENT AND BUILDING STAKEHOLDER SUPPORT

A robust pre-project assessment of the need for a research reactor helps to consolidate the user base and so ensure sustained, high, facility utilization throughout the reactor’s operating life. High utilization is often needed to justify ongoing resource commitments to long term safety, security, environmental stewardship, availability and reliability. Developing a broad stakeholder base, and organising the research reactor project to satisfy its needs will also help to maximize political and financial support for the project.

The process begins with the formation of an Assessment, Marketing and Project Team (AMPT). The AMPT will identify the stakeholders, assess the stakeholder needs and translate these into outline specifications for the reactor and its ancillary facilities. The AMPT should also identify issues that require government attention, and consult with the appropriate decision makers and their advisors. Figure 4 shows this process schematically, and the following sections describe the process in more detail.

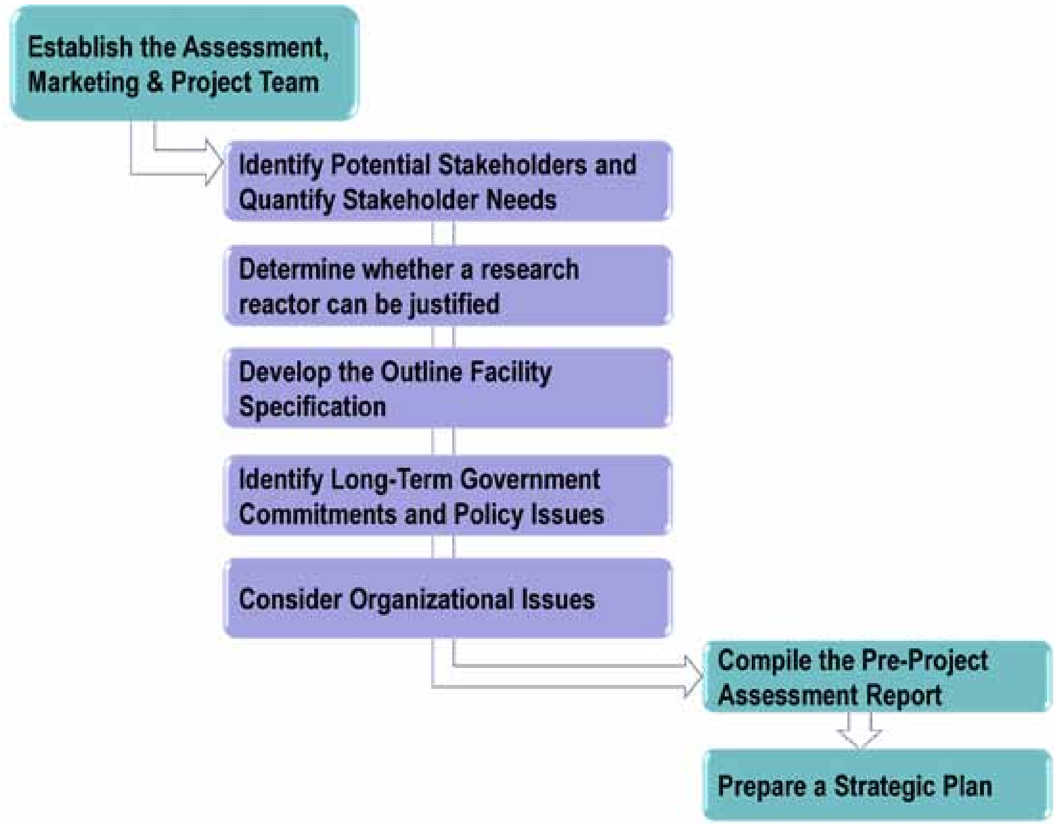

FIG. 4. Pre-project assessment process.

3.2. FORMING THE ASSESSMENT, MARKETING AND PROJECT TEAM

The AMPT will determine whether the research reactor project is justified, and will then develop the functional specification for the research reactor. It will also build and strengthen the network of funders, stakeholders and interested parties that will underpin the reactor's success and sustainability.

The AMPT should include people with high credibility and access to both the stakeholders and the government. The AMPT will be most effective if its chairperson has excellent connections to government. Obtaining the views of potential stakeholders, developing the associated needs document, and outline facility specifications, marketing the facility's benefits and capabilities, developing the statement of infrastructure needs and policy issues, and translating these into effective action all require access to decision makers in stakeholder organizations and in the government.

The AMPT members should be qualified people who have experience with, and particular interest in, the operation or utilization of research reactors. The members should include experienced managers that are familiar with the development of economic analyses and strategic plans, as well as technical specialists with advanced degrees in physics, nuclear engineering or a related technical discipline. The team should have experience of previous research reactor projects, research reactor management oversight, research reactor utilization, research reactor engineering support, and research reactor operation and maintenance. It is important that the membership include people that are familiar with all areas of potential research reactor utilization. A helpful reference is IAEA Technical Reports Series No. 455, Utilization Related Design Features of Research Reactors: A Compendium [5]. Previous successful experience in advocating for major facilities or projects within the country would also be highly beneficial.

If adequately qualified and experienced people are not available within the relevant national bodies, independent external expertise should be sought to strengthen the qualifications and experience of the team.

3.3. IDENTIFY STAKEHOLDER NEEDS

The AMPT should nominate one or more of its members to survey potential stakeholders.

3.3.1. Identify potential stakeholders and supporters of the research reactor

The potential stakeholders and supporters of the research reactor should be identified, both nationally and regionally. The stakeholders will include:

— Those whose current work could be better performed at the research reactor;
— Those who may start up new work through the enhanced opportunities offered by the research reactor;
— Those (for example government departments) who may value the research reactor as a means to achieve policy goals or other objectives.

Each potential stakeholder will have a different perspective on the *benefit* and *value* that they can derive from a research reactor, as shown schematically in Fig. 5.

The AMPT should quantify and evaluate the *relative importance* of each of the research reactor applications for each of the identified potential stakeholders. If possible, representatives of stakeholder groups should be consulted during this process, both to better understand the potential value and possible characteristics of the research reactor, and to present information on how a research reactor might contribute to their goals. In many cases, potential stakeholders will be unaware of the full capability of a research reactor and how they might benefit in terms of improved science, productivity or service delivery.

Prepare a list of potential shareholder organizations to be contacted for the pre-project planning and consultation, as shown in Table 6, and then identify organizational facilitators, as shown in Table 7.

In collaboration with the organizational facilitators, identify relevant individuals, groups or authorities within each listed organization who will take part in the survey. Refer to Table 8.

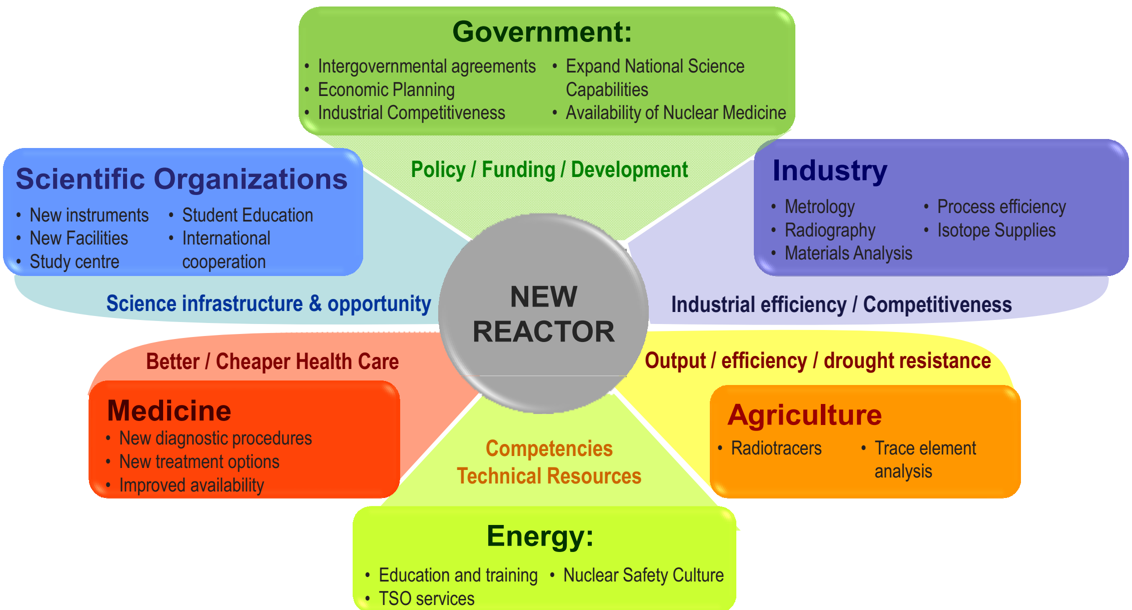

FIG. 5. Possible stakeholders and supporters of a research reactor.

TABLE 6. ORGANIZATIONS TO BE CONSULTED IN THE PRE-PROJECT PHASE

Type of organization	— Examples of potential stakeholders/issues of interest
Universities/colleges	— Professors/students concerned with nuclear science and engineering
Research centres	— Specialists with knowledge of research reactors — Users of neutron beams in scientific research — Current/potential stakeholders of research reactor services
Commercial and industrial	— Users of radioisotope tracing techniques — Users of activation analysis to assess wear, impurity levels, etc. — Users of neutron radiography to examine complex components — Users of radioisotopes for process monitoring and tracing
Hospitals	— Clinicians using radioisotopes in diagnosis and treatment
Government departments involved in:	
Health	— National health/nuclear medicine policies and plans — Cancer screening, diagnosis and treatment
Science and technology	— National science and technology policies and plans
Environment	— National environmental policies and plans — Air and water pollution studies — Water resource management
Agriculture	— National agricultural policies and plans — Studies in soil management — Elemental analysis of food stuffs — Use of radioisotopes to optimize fertilizer utilization
Industry	— National policies for industrial development and competitiveness — Production cost reductions through applications of nuclear techniques
Culture and heritage	— National policies and plans for heritage preservation — Artwork verification — Dating of artefacts
Mining	— National policies and plans for mine development — Trace element measurement by neutron activation analysis.

TABLE 7. LIST OF POTENTIAL STAKEHOLDER ORGANIZATIONS

Potential stakeholder organization	Organizational facilitator and position	Contact details
University of XXYY	Prof MMMMM	Address, Email, T/phone
FGH Petroleum	Mr GGGGG	Address, Email, T/phone
BNM Mining	etc	etc
CDT Industry	etc	etc

TABLE 8. LIST OF IDENTIFIED PERSONS/GROUPS WITHIN A POTENTIAL STAKEHOLDER ORGANIZATION

Name of organization: University of XXYY
Organizational facilitator: Prof MMMMM

Identified person or group	Contact details
Electronics group	Dr HHHHH telephone 123456
Materials science faculty	Mr BBBBB emailbbbb@yahoo.com
Mr Z	Address, Email, T/phone

3.3.2. Develop stakeholder profiles and targeted presentation materials

For each identified person in Section 3.3.1, develop a potential stakeholder profile by considering their objectives, and their interest or need for the research reactor utilization features and facilities listed below, noting that the list is not meant to be exhaustive and not all items may be pertinent. Where possible, record in the stakeholder profile what benefit each specific feature will provide by answering the questions:

— How would this feature help the identified person?
— How much would this feature help the identified person?

In each case, the answers should be related to the priorities and objectives of the identified person (as the implemention team understands them). The possible applications of the research reactor are discussed in IAEA-TECDOC-1234 [9]:

— Education and training;
— Neutron activation analysis;
— Prompt gamma neutron activation analysis;
— Radioisotope production;
— Geochronology (argon geochronology, fission track geochronology);
— Transmutation effects including silicon transmission doping, materials irradiation, gemstone coloration, actinide transmutation);
— Neutron radiography;
— Material structure studies (neutron beam/scattering science and applications, cold and ultracold neutron sources);
— Positron source;
— Neutron capture therapy;
— Fuel and materials testing;
— Instrument testing and calibration.

Prepare presentation materials for the identified persons that sets out the possible contribution of the research reactor to the individuals objectives. Use prepared surveys to collect relevant data in discussion with the identified individuals, based on their experience, qualifications, current and expected future technical needs. It should be noted that presentations are more effective if they are customized for each target audience.

The needs of these stakeholders are not only diverse, but they also change over time. The priorities and needs that underpin the decision to build a research reactor will evolve during the 40 or more years of research reactor operating life. For example, advances in science and industrial practices will tend to make the initial scientific, industrial or medicinal mission obsolete within 20 years or so. Yet the reactor will continue to require support for its operation, safety, and security, and it will require funds for its eventual decommissioning. As noted in Section 1.7, obsolescence of the initial reactor mission could result in the reactor becoming progressively less well utilized over time, while at the same time facing increasing budgetary pressures.

Planning and organizing for this diverse and changing nature of the research reactor mission is a major challenge. Meeting that challenge requires the development of solid basis of stakeholder support at the outset coupled to organization and reporting structures for the reactor that make it possible to periodically review, and when necessary, refocus the reactor mission. This support and ability to adapt will allow the reactor to play its full role throughout its life cycle. Questions that should be addressed in this context include:

— Who are the stakeholders (see Section 3.1) and what are their current and future needs?
— What are the major stakeholder priorities and trends?
— What technical options or flexibilities should be considered in the initial design?
— How will the relevance of the reactor mission be reviewed and adapted if necessary?
— What are the implications and challenges for organization structure and management?

When reviewing future stakeholder needs it should be borne in mind that some 5 to 10 years will be required to design, construct and commission a new research reactor. Therefore the anticipated stakeholder requirements in at least 10 to 15 years time are an appopriate initial reference point for planning the research reactor. This timeframe would be after the research reactor is constructed and brought into service, but still within a credible forecasting period. Discussions with stakeholders and experts can be used to determine the stakeholders' long term goals and to extrapolate current stakeholder priorities and trends to support this planning horizon.

Relevant governmental departments will have perspectives and objectives for strategic development of science, industry, and nuclear medicine, for example, that can provide a context for planning. The representatives of stakeholder organizations will have insights into potential developments in their respective technical spheres. Experts at the IAEA can also help by providing an external perspective based on global trends and experience, and by facilitating sharing of best practice in research reactor project planning and implementation. Recent conference proceedings should be reviewed for information on uses and future trends in research reactors and a conference should be attended, if possible, in order to take advantage of the experience of other research reactor operators.

As the stakeholder profiles are developed, the needs for the research reactor services should become increasingly clear. To assess and prioritize these needs it is helpful to ask the following questions:

(1) What problems will the reactor solve?
(2) What information or intellectual property (IP) will it provide?
(3) Will it generate any commercial income?
(4) What will be the impact of satisfying these needs?
   — Scientific;
   — Technical (IP);
   — Social;
   — Economic.
(5) Is the identified need a national priority, and if so:
   — Is it a key component of a formal national policy?
   — Is it tied to existing legislation?
   — Is it part of the government's international and regional commitments?
   — Will it satisfy government strategic position such as possible future NPP development?
(6) Will the associated stakeholder provide financial support to help meet:
   — Initial project cost;
   — Ongoing operating costs?

3.4. DEVELOP A DRAFT FUNCTIONAL SPECIFICATION FOR THE RESEARCH REACTOR AND ITS ANCILLARY FACILITIES

The needs and applications should be translated into a draft functional specification for the research reactor and its ancillary facilities that will allow the appropriate technical features to be developed.

The initial focus on functional requirements allows a more systematic development of the technical specification. A recent, successful new research reactor project took a deliberate decision to not specify the research reactor type or other technical details at this stage of the process, but focussed on specific performance requirements from a stakeholder perspective only, developed from the needs assessment. These performance requirements included the sizes and locations of neutron beams, and the associated neutron fluxes and spectra, and the volumes and shapes, neutron fluxes, neutron spectra, maximum flux buckling and cooling requirements of the irradiation facilities. At this time, any reactor test loops that are needed should be specified together with the appropriate auxiliary equipment for data acquisition and control, and the associated thermal hydraulic systems.

A list of possible functional issues is shown in Table 9.

In most cases, there will be some needs that cannot be fully satisfied if the research reactor is to be completed on the required timescales and within the available budget. It will be necessary to prioritize the needs and adapt the functional specification. Accordingly, the functional specification must undergo preliminary evaluations of:

— Time and cost to design, construct and commission;
— Safety and regulatory requirements;
— Resources required to operate and maintain (including fuel costs);

TABLE 9. RESEARCH REACTOR FUNCTIONAL SPECIFICATION

Reactor functional requirement	Current	Future
1. The frequency and duration of reactor use		
2. Irradiation facilities: size, neutron flux and energy spectrum for each		
3. Temperature and pressure requirements of material test facilities		
4. Required measurement capabilities		
5. Volume requirements for irradiation positions (e.g. for silicon doping)		
6. Auxiliary support equipment and facilities		
7. Number of neutron beam locations, beam sizes, neutron fluxes, and neutron spectra		
8. Access of users to the reactor facilities and separation of scientific and reactor operations		
9. Radioisotope processing abilities		
10. Waste management storage capability		
11. Spent fuel storage duration and restrictions		
12. Requirements to vary reactor power level for education and training purposes		

- Resources to dismantle and decommission;
- Impact on the costs of radioactive wastes and spent fuel management and disposal;
- Regulatory (nuclear, environmental, etc. oversight and approvals of each item above).

The balancing of functional capability against the investment and operating costs is a complex financial calculation. Investment cost can be estimated on the basis of project experience elsewhere, and possible with the advice of research reactor suppliers. The operating costs are harder to determine, in part because of the duration of the operating costs. The financial uncertainties arising from such a long period are difficult to master. For example, the fuel cycle cost constitutes a substantial fraction of the operating costs, but reliable price indexes for fuel over such a long time are not available.

When this preliminary prioritization is complete, a facility concept design can be prepared by defining the following:

- Reactor power level;
- Irradiation and beam facilities requirements for example for isotope production;
- Safety performance requirements;
- Security and safeguards requirements;
- Core design and performance (nominal operating cycle and fuel design);
- Fuel cycle management requirements (fresh/spent fuel storage, inspection hot cells, handling equipment and casks);
- Ancillary facilities (beam hall, office space, hot cells, etc.);
- Integration within a nuclear centre.

The research reactor experience in the European Union highlights two generally successful approaches to specifying a research reactor:

- A research reactor that heavily specialized in one particular discipline, that is most attractive for the relevant stakeholders [11–12];
- A very flexible research reactor offering multiple services [13]. These reactors have core geometries and additional facilities to accommodate many different requests. This type of research reactor would normally have a highly adaptable hot-cell facility complex associated with, that has attractive and frequently renewed test and microscopy facilities.

The first approach requires a dedicated staff that is deeply involved in the specialty. The latter approach requires both a research reactor and hot-cell laboratory staff that are able to fulfil requirements of many clients by strength in nuclear and thermal hydraulic design of custom made rigs and loops. Consequently, this approach is only possible if sufficient time and budget is allotted to educate, train and obtain experience for the staff to become knowledgeable in their fields. This latter approach is often associated with large facilities, which are costly to operate and thus need a large client base that is not easily established for a first reactor.

It is a requirement of the IAEA Safety Standards to set aside decommissioning funds before the start of operations of a research reactor. It is also required to address decommissioning issues in the research reactor design. Appropriate design for safe decommissioning and minimization of costly radioactive waste would lead to a reduced decommissioning budget, and lower overall project costs, even if the initial investment for reactor construction is higher.

3.5. IDENTIFY LONG TERM GOVERNMENT COMMITMENTS ASSOCIATED WITH OPERATION OF A RESEARCH REACTOR

The construction of a research reactor raises many issues with implications for domestic and international government policy, in particular for a first research reactor. The AMPT should develop a thorough understanding of the long term governmental obligations and commitments and the national strategy to achieve them before a decision on implementation is taken.

These commitments and obligations include:

- Adherence to the relevant international treaties, conventions, and codes. This is an important commitment by the State in order to provide assurance to the wider international nuclear community;
- The establishment of a national legal framework for the nuclear sector;
- The establishment and continued resourcing of an independent and effective regulatory body;
- The long term public financial resources to support all phases of the research reactor project (design, construction, commissioning, operation, decommissioning and final waste storage);
- Procurement of fuel for the reactor;
- Spent fuel storage, processing, repatriation or final disposal, as appropriate;
- Long term radioactive waste management issues, including facilities for long term storage and final disposal;
- Security for the research reactor facilities and technology and the radioactive materials it will generate;
- Intergovernmental agreements to secure ongoing technology support, and spent fuel and waste management;
- The need to develop and retain the necessary skills.

3.6. DEFINE THE ORGANIZATIONAL STRUCTURE AND CONTEXT

The AMPT should consider the appropriate organization structure, reporting relationships and internal performance measures for the research reactor operator.

Experience has shown that the organization structure and reporting relationships should be matched to the research reactor mission and strategic plan to reduce the likelihood of underutilization and financial stress. For example, a research reactor intended for basic scientific research could reasonably be controlled and funded from the Ministry of Science. However, such control and funding may create conflicts that adversely impact a research reactor dedicated to commercial materials testing or isotope production.

Similarly, if the sole staff incentive scheme for a research reactor operator dedicated to industrial or commercial services is publication of papers in scientific journals (as may be required from an institute that belongs to the Academy of Sciences), the absence of a link between customer satisfaction and staff motivation can be expected to create performance and funding conflicts.

To be sustainable, the funding for the research reactor operations, the internal organization of the research reactor operators, and its reporting relationships to senior decision makers should take into account the reactor’s mission and the priorities of its stakeholders.

Another issue to be accounted for organizationally is the evolution of the research reactor mission over time. As noted earlier, the demand for science and services will change, and research reactor services that are in demand when the research reactor project starts may become obsolete with advances in technology. Accordingly, the governance of the reactor operator should include inputs from all stakeholder groups. For example, this input may be provided by stakeholder representation of the governing board or directorate, or through an external consultative body. The intent will be to help the research reactor operator to adapt its operations, funding and management as needed to remain relevant as priorities change.

3.7. CONSIDER REGIONAL AND INTERNATIONAL COOPERATION

From a policy perspective, research reactor capabilities can be provided by a national research reactor, a regional research reactor, or subscriptions to research reactors in other countries. It is recommended that, as part of the Pre-Project Assessment, a Member State considers the possible role of the research reactor in the regional and international contexts and the requirements and options for regional and international cooperation. The needs assessment may be extended to consider the wider stakeholder network of the supra-national approach. The advantages and disadvantages of the regional approach are discussed in Annex III.

3.8. COMPILE FINAL STAKEHOLDER NEEDS INTO A PRE-PROJECT ASSESSMENT REPORT

The Pre-Project Assessment Report is one of the main outputs of the AMPT, and will be used to inform national decision makers, project sponsors, users and other stakeholders. It will contain the results of the potential stakeholder interviews and subsequent evaluation, and the regional and governmental issues discussed above.

The report will define key facility stakeholders, describe their needs and any possible financial support and will discuss the relevant national priorities. The concept of a reactor centre and appropriate ancillary facilities to fully exploit the research reactor should be considered.

To support the justification of the research reactor, the document should present the advantages and disadvantages of other options for satisfying the stakeholder needs; for example the use of other technologies such as synchrotrons, cyclotrons, or neutron spallation sources, and the options for subscription to a regional centre as an alternative to construction of a national research reactor facility.

The pre-project assessment report will include a utilization study. References for this utilization assessment are the IAEA’s Technical Reports Series No. 455, Utilization Design Features of Research Reactors: A Compendium and IAEA-TECDOC-1234, Applications of Research Reactors [10].

The report will provide the conceptual facility functional design, including research reactor type and power, ancillary facilities, rough project costs and schedule estimates. To prepare this document, the AMPT may be supported by external experts and consultants, if necessary.

The report should include a scope and prioritized objectives for the project (site selection, utilization, human resources, training and infrastructure needs, etc.).

3.9. PREPARE THE PRELIMINARY STRATEGIC PLAN

The Preliminary Strategic Plan is the second major output of the AMPT. It will be used to help gather support from the potential stakeholders, suppliers and international support, as well as providing clear guidance to national decision makers on the actions expected of them for a safe and successful research reactor project. The Strategic Plan will be updated and enhanced regularly during the research reactor design, construction and operation.

The Preliminary Strategic Plan should include the research reactor and its ancillary facilities, and the research centre if appropriate, based upon the findings of the Pre-project Assessment Report. The Strategic Plan will summarize the justification for the research reactor and its ancillary facilities, and develop detailed recommendations for the financial and organizational structure of the research reactor and its associated research centre and ancillary facilities, as well as the policy decisions and actions required from the government.

The Preliminary Strategic Plan will clearly set out the research reactor purpose, utilization, stakeholders, expected performance indicators for a non-technical audience, and should include a strengths, weaknesses, opportunities and threats (SWOT) analysis, as described in IAEA-TECDOC-1212 Strategic Planning for Research Reactors.

Once the Member State has produced the affirmative decision documents assessing the importance and purpose of the research reactor, the next step is to start the development of the necessary infrastructure to design, construct, and safely and securely operate the facility, as described in the next sections.

4. MILESTONE 1: READY TO MAKE A KNOWLEDGEABLE COMMITMENT TO A RESEARCH REACTOR PROJECT

During the Phase 1, the Member State completed the Pre-Project Assessment and Preliminary Strategic Plan and determined that there are scientific, industrial or medicinal needs that may justify the construction of a research reactor. However, before embarking upon the research reactor project, the Member State must develop a comprehensive understanding of the obligations and commitments involved, and ensure that there is a long term national strategy and resources available to discharge them. This work will culminate in the attainment of Milestone 1 and the production of the Feasibility Report which demonstrates that the Member State is in a position to make an informed decision whether to proceed with the research reactor project. The Feasibility Report will incorporate and update the Pre-Project Assessment and Preliminary Strategic Plan and integrate these with the analysis of the obligations, commitments and resources required.

4.1. NATIONAL POSITION

A nuclear research reactor requires long term commitments, both nationally and internationally. Demonstrable recognition of these commitments and a determination to fulfil them forms the basis for a credible national position to construct a research reactor. The obligations and liabilities of a research reactor project extend for several decades, including the post-operations commitments to decommissioning and radioactive waste management. The research reactor project requires a full supporting infrastructure of regulatory, safety, security capabilities and waste management facilities. It is therefore of utmost importance that the Government fully understands the scope and timescales of the commitments at the outset of a research reactor project. The commitment to use only LEU for the research reactor fuel and applications should be made at this stage.

The AMPT should have developed a full understanding of the commitments and documented these in the Strategic Plan for the research reactor project. The review of, validation, and action on these commitments for a first nuclear project can be best achieved by an RRPIC that is vested with approval and enforcement authority.

A condition for Milestone 1 is that the RRPIC has been established with strong reporting relationships to the government, preferably at the ministerial level, and with the necessary credibility internally and internationally. Adequate staffing, funding and time have been provided to carry the RRPIC’s activities through to completion. The members of the commission have access to the expertise necessary to address all relevant issues, with any gaps in the expertise of the RRPIC members filled by retaining external consultants/experts. However, the leadership of the RRPIC and the responsibility for the adequacy of the infrastructure remains with the Member State.

The RRPIC should satisfy itself that a comprehensive study of the commitments and liabilities of a research reactor project have been satisfactorily completed, and it should ensure that appropriate actions are taken prior to the construction of the facility.

The key issues which require action include:

— Statement of commitment to ensuring safety, security and non-proliferation of nuclear material;
— Acceding to the relevant international legal instruments;

— Indentification of any intergovernmental agreements required to support fuel cycle services or technological support;
— Active participation in the Global Nuclear Safety Regime, and promoting leadership and management for safety, including the building of a strong safety culture;
— Implementation of a comprehensive legal framework covering all aspects of nuclear law, which includes safety, security, safeguards and nuclear liability and other legislative, regulatory and commercial aspects;
— Establishing an effective independent, and competent regulatory body responsible for safety and security;
— Availability of adequate human resources to operate, maintain and regulate the research reactor and its ancillary facilities;
— Policies, programmes and resources for the decommissioning and the safe, secure management of spent fuel and radioactive waste.

4.2. NUCLEAR SAFETY

An integral part of being able to make a knowledgeable commitment to a research reactor project is recognition of the importance of safety. Safety is integral to all activities associated with the design, construction and operation of a nuclear facility.

A first research reactor poses specific requirements for a national nuclear infrastructure and for participation in the international network on nuclear safety. At this initial stage of the research reactor project, the focus should be on the recognition of the need to implement all the provisions of the Code of Conduct on the Safety of Research Reactors at the start of the research reactor project. These include:

— The IAEA Fundamental Safety Principles;
— The operating organization has the prime responsibility for safety;
— Effective leadership and management for safety;
— Recognition of various safety design principles and understanding of different safety features;
— Arrangements to prevent and mitigate accidents, including arrangements for emergency preparedness and response;
— Adequate resourcing of all safety-related activities, both from an operational and regulatory point of view;
— Participation in the Global Nuclear Safety Regime.

4.3. MANAGEMENT

Milestone 1 requires that both the AMPT and RRPIC have been formed, with the RRPIC having review and approval authority for all issues associated with a research reactor project.

The AMPT has completed the pre-project assessment report, and has included the following managerial issues:

— The compatibility of the recommended research reactor with the national strategies for science, energy, industry, and nuclear medicine;
— Mechanisms for sustained communications with stakeholders;
— Suitable site locations for nuclear facilities;
— Personnel and financial resource requirements and options;
— Organization of project activities and designation of responsibilities and authorities;
— Ownership options and operational responsibilities, including options for regional or international cooperation.

The RRPIC has reviewed all of the information in the Pre-project Assessment Report and the Strategic Plan and has determined which actions must be taken pursuant to a decision to proceed with the research reactor project, including the following management issues:

— Development of appropriate human resources;
— Implementation of a nuclear safety and security culture;
— Implementation of safety, security, safeguards, health, environment and quality assurance programs;
— Use of ‘Risk Analysis’ methodology for the management of the project, including preparation of a list of recognized experienced risk auditors.

4.4. FUNDING AND FINANCING

At Milestone 1, financial resources have been provided for the RRPIC to review the Pre-Project Report and Strategic Plan, and to develop an understanding of the financial commitments and long term liabilities associated with the research reactor. Financial resources have also been provided for the drafting and promulgation of the necessary legislation and for the expansion of an existing, or the establishment of a new, regulatory body with the necessary resources to ensure competence.

The RRPIC considerations have included the funding and financing requirements for:

— The construction, safe operation and decommissioning of the research reactor;
— The long term management of spent fuel and radioactive waste;
— The creation of a competent reactor operating staff;
— The cost operations of a competent regulatory body;
— The creation of the necessary regulatory framework;
— Safety, security and safeguards arrangements for the protection of nuclear facilities and materials;
— Maintaining a reasonable level of stakeholder involvement.

The development of strategies for the funding and financing of all elements of a research reactor project will demonstrate recognition of these commitments.

4.5. LEGISLATIVE FRAMEWORK

A research reactor project must be supported by specific nuclear-related legislation which may not exist in a Member State when entering Phase 1. The requirements for a legislative framework should be developed by the AMPT and the RRPIC and be discussed with the appropriate government institutions and agencies. Clearly, the knowledge and experience of the regulatory body that controls radiation sources is a valuable resource in this respect, and existing legislation for radiation protection, radioactive waste management and transportation safety should be taken into account.

At Milestone 1, the basic elements should have been reviewed to recognize what must be accomplished, including:

— Legislation to clearly designate responsible institutions or bodies, and their relationships with the research reactor;
— Legislation dealing with establishing effective independent regulatory authorities, a system of licensing, inspection and enforcement and with all subject areas of nuclear law; i.e. radiation protection, radioactive material and radiation sources, the safety and security of nuclear installations, emergency preparedness and response, transport, radioactive waste and spent fuel, nuclear liability and coverage, safeguards, export and import controls;
— Legislation on foreign investment, including the roles of foreign entities, vendors and suppliers, and intellectual property rights;
— Legislation dealing with the roles of national government, local government, stakeholders and the public;
— Legislation dealing with fuel cycle issues in general and the ownership of nuclear material;
— Provisions for the development of human resources to assure the continued integrity of the peaceful nuclear programme;
— The commitment to use nuclear technology for peaceful purposes.

4.6. REGULATORY FRAMEWORK

At Milestone 1, the regulatory body may or may not already exist. In any case, emphasis should be given to assessing and understanding the fundamental elements of the regulatory framework and the appropriate position of the regulator in the governmental structure. Due consideration should be given to whether the existing regulatory body (which might be dealing with radiation protection, transport, etc.) will be expanded, or whether a new regulatory body will be created. It is advisable to have a single regulatory body, however, if different authorities will coexist, then it is important that they coordinate their activities and that their respective roles and responsibilities are clear.

The fundamental elements of the regulatory framework include the designation of an effective, independent and competent regulatory body with:

— Clear authority and adequate human and financial resources;
— Authority to obtain technical support as needed;
— Authority to implement international obligations including IAEA safeguards;
— Authority to engage in international cooperation;
— Clearly defined relationships between the regulatory body and other organizations;
— Core regulatory functions assigned for development of regulations, licensing, review and assessment, inspection, enforcement and public information;
— Provisions to protect proprietary, confidential and security information;
— Provisions for stakeholder and public information and interactions.

4.7. SAFEGUARDS

Non-nuclear weapon States that are party to the NPT should have a Comprehensive Safeguards Agreement (CSA) conforming to INFCIRC/153 (Corrected), which is in force with the IAEA. States with a CSA should have also concluded an Additional Protocol (AP) on the basis of INFCIRC/540 (Corrected), providing for the implementation of the IAEA strengthened safeguards system, while many States that do not have any nuclear facilities have concluded a Small Quantities Protocol (SQP), which has the effect of holding in abeyance many of the detailed provisions of the CSA. The CSA together with the AP contain specific obligations undertaken by the State to accept safeguards, and the necessary rights and tools for the IAEA to implement safeguards in order to provide a credible assurance to the international community and the public that the State complies with its obligations under the NPT for the exclusively peaceful use of nuclear technology. The implementation of safeguards is applied, as appropriate, to the nuclear material and activities within the State or anywhere under the control or jurisdiction of the State.

At Milestone 1, communications with the IAEA regarding the State’s consideration of building a facility should be established. In order to exercise the required State control and to facilitate cooperation with the IAEA in implementing the CSA and AP provisions, the State should establish and maintain an adequate SSAC. This is an obligation under the CSA independent of the amount of nuclear material or the extent of nuclear applications in the State. The establishment of a SSAC serves a useful purpose; that is to ensure the effective implementation of the safeguards that are applied. In this respect, the recognition of the need to implement the following factors is considered of primary importance when establishing safeguards in any State:

— Cooperation between the State, reactor operating organization and IAEA in safeguards implementation;
— Adequacy of the SSAC in relation to the IAEA requirements for accounting for and control of nuclear material;
— Capability of the IAEA to independently verify the completeness and correctness of the State’s declaration of nuclear material quantities and locations which has been reported in accordance with its safeguards agreement.

4.8. RADIATION PROTECTION

The RRPIC should develop an understanding of the specific radiation hazards presented by research reactor operation. These include the hazards associated with nuclear fuel use and management, neutron beam lines, radio-isotopes production, and materials that may be activated in the reactor. The IAEA's Basic Safety Standard (IAEA Safety Series No. 115) and other IAEA safety standards provide guidance for the operating organization and regulators to establish radiation protection requirements and practices.

At Milestone 1, there should be an awareness and understanding of the radiation hazards posed by research reactor operation and nuclear material transportation and storage, as well as waste management, and the need to enhance national laws and programmes. Training of radiation protection personnel should be provided for both the regulatory body and the operating organization.

4.9. RESEARCH REACTOR UTILIZATION

In order for the Government to accept that the research reactor is likely to be adequately utilized during its operating life. The RRPIC will confirm that the Pre-Project Assessment has been completed and that the rationale for the research reactor and its ancillary facilities is soundly based. It should also confirm that a Strategic Plan exists including funding mechanisms and other resource requirements, and that mechanisms to adapt the reactor mission to evolving stakeholder needs have been addressed. To this end, the RRPIC should confirm that:

- The range of potential utilization of the research reactor have been studied and documented;
- The potential major stakeholders for the research reactor have been identified and consulted;
- The options for regional and international cooperation have been properly considered;
- Mechanisms are identified to encourage input from all stakeholder communities on potential areas of research reactor utilization;
- A Strategic Plan for the research reactor exists, including funding and other resource requirements.

4.10. HUMAN RESOURCE DEVELOPMENT

Acquiring and maintaining all necessary personnel competences for the research reactor is a key, and often challenging, aspect of the research reactor project. The RRPIC should ensure that the AMPT, the proposed operating organization, and the regulator identify the specialized training for the full range of scientific and technical disciplines needed for the research reactor project. The RRPIC should ensure that a realistic plan to develop and maintain the human resource base has been developed in conjunction with all parties to be involved in the research reactor project. Even if much of the initial knowledge and skills are to be provided by foreign sources of manpower, it is recommended that long term knowledge and skills to manage and oversee the project should be developed and kept within the nation.

At Milestone 1, firm plans should have been developed to obtain the resources needed throughout the life of the research reactor project. The following key issues should be considered:

- Anticipation of long term human resource and knowledge management needs and recognition of the full range of scientific and technical disciplines needed for a fully functioning research reactor project;
- Assessment of the availability of those disciplines within the Member State;
- Assessment of the national educational capabilities and the option for foreign education and training;
- Identification of the specialized training needed even for experienced personnel in nuclear safety, security, safeguards, radiation protection and management systems;
- Training and development of personnel for their assigned responsibilities.

4.11. STAKEHOLDER INVOLVEMENT

The users and other stakeholders of the research reactor are essential to its long term viability, and should be closely involved in the specification of the research reactor capabilities, as well as consulted on important design decisions. At Milestone 1, the AMPT should have systematically identified and consulted the research reactor stakeholders regarding possible uses of the reactor, and the Pre-project Assessment Report should have been issued.

Another key commitment to be understood by the government as it contemplates a research reactor project is the importance of informing the public and the international community by maintaining open and timely interaction and communications.

The appropriate conditions established at this phase are:

— Survey public opinion to determine the degree of knowledge and receptiveness to the research reactor project;
— Develop pubic information tools that respond to the surveys and clearly explain the reasons for the government interest in and the societal benefit to result from the research reactor project;
— Train and have available senior spokespersons to interact with stakeholders in response to any request.

4.12. SITE SURVEY, SITE SELECTION AND EVALUATION

The RRPIC should ensure that general site assessments and surveys have been conducted on each of the candidate sites. At Milestone 1, these will be based largely on existing data and information about each of the site study elements discussed in Section 2.16. The IAEA safety standards provide one way to establish requirements and guides for site evaluation. The sites should be ranked in order of merit.

Site surveys may be subdivided into three distinct phases:

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

4.13. ENVIRONMENTAL PROTECTION

The unique environmental issues associated with a research reactor should be analyzed by the RRPIC. The construction and operation of nuclear facilities should receive the same scrutiny and compliance with the national environmental laws and regulations as any other research or industrial facility. The potential environmental impacts and improvements should be communicated as part of the overall research reactor development programme.

The responsibilities of the regulatory body and other environmental agencies should be clearly defined, and formal environmental studies and reports should be conducted early in the project beginning with site selection.

At Milestone 1, the RRPIC should have considered:

— Land use, water use and environmental effects of low level radioactive effluents from normal operation and maintenance of the research reactor and its ancillary facilities;
— Whether the existing environmental laws and regulations need to be updated to cover the research reactor facility construction and operation.

4.14. EMERGENCY PREPAREDNESS AND RESPONSE

To be able to make an informed decision regarding a research reactor project, the RRPIC should understand the requirements for emergency planning. This includes identifying national institutions that could support emergency preparedness and response and the steps that need to be taken so that these are able to respond in a coordinated manner to an emergency. These institutions include the appropriate branches of government, the operating organization, and the emergency services organizations (such as police, fire-fighting, medical services, etc.). The emergency planning requirements must be set by the regulatory body, in accordance with national law. Modalities will need to be established and resourced to inform the public and neighbouring States if necessary.

The operating organization will be responsible for emergency response planning and for ongoing coordination with local and national government and the emergency services. For high power research reactors, plans for emergency sheltering or public evacuation may be required. In such an event, the operating organization would recommend that action is taken, but authority to order this would remain with local governmental officials. The provisions made for public protection by emergency planning should be communicated as part of the public information effort.

Milestone 1 requires an appreciation of the importance of emergency planning and agreement on allocation of roles of the operating organization and governmental authority as well as consideration for future membership to the conventions on early notification of a nuclear accident and on assistance in the case of a nuclear accident or radiological emergency.

4.15. NUCLEAR SECURITY

An integral part of becoming ready to make a knowledgeable commitment to a research reactor project is the recognition of the importance of security. Security is a necessary component of all activities associated with the design, manufacture, building and operation of a nuclear facility. New entrants to a research reactor project need to take early actions to fulfil their responsibilities for nuclear security.

At this initial stage of the research reactor project, acknowledgement of the requirements for security and physical protection and the identification of necessary legislation are sufficient to achieve Milestone 1. This includes the need for the following:

- Application of the IAEA Nuclear Security Fundamentals;
- The operation organization to have prime responsibility for security;
- An effective legal and governmental framework for security, including an independent regulatory body;
- Effective leadership and management for security;
- Arrangements to prevent and mitigate malicious acts;
- Subscription to intergovernmental instruments on security (e.g. legally binding Conventions, the IAEA security guidance);
- Share knowledge and experience through participation in international and regional organizations, including development of IAEA reports such as the Nuclear Security Series Guidance, and participation in the peer review process.

4.16. NUCLEAR FUEL MANAGEMENT

The organizations involved with the research reactor project should consider the issues of nuclear fuel supplies and management early in the research reactor project, as these may influence many of the technical decisions relating to the research reactor. At Milestone 1, the RRPIC should be informed about the nuclear fuel cycle issues and alternatives, and should have identified the need to obtain, manage and dispose of, fuel supplies throughout the reactor life as a key issue that will impact the bid specification for the research reactor.

The long term management and eventual disposal of spent fuel is a major issue that must be acknowledged by the RRPIC. To be ready to make a knowledgeable commitment to a research reactor project, the RRPIC should have identified the key policy and financial requirements for spent fuel management, including the need to either create national facilities for final disposal of spent fuel or to negotiate for spent fuel processing in other countries.

4.17. RADIOACTIVE WASTE

To be ready to make a knowledgeable commitment to a research reactor project, the RRPIC should have a clear recognition of the additional responsibilities for radioactive waste associated with a research reactor project, and the need to be able to communicate how to safely and securely deal with this radioactive waste. This includes the need to review and, if necessary, enhance the existing national radioactive waste management policy.

To attain Milestone 1, the RRPIC should have:

— Knowledge of the current national capabilities, regulatory framework and experience with radioactive waste handling, storage, transport and trans-boundary movement and disposal;
— Recognized the need to formulate a relevant RWM policy;
— Considered different options for radioactive waste management and disposal;
— Knowledge of the additional volume and isotopic content of low and intermediate level waste from a research reactor facility, including the potentially large waste volumes from reactor decommissioning;
— Recognized that becoming a contracting party of the Joint Convention will provide the means for mutual learning in the global scientific community;
— Recognized the long term safety requirements and cost implications of radioactive waste management and disposal.

4.18. INDUSTRIAL INVOLVEMENT

Initial considerations by the RRPIC should include the assessment of opportunities and challenges for national industrial involvement in the research reactor project. This includes recognition of the qualifications necessary to provide nuclear equipment and services, including the need for the strict application of quality standards for nuclear equipment and services that are much more stringent than for other industrial operations. A supplier of the research reactor would need assurance the industrial capabilities are adequate before agreeing to any scope of participation for the domestic industry.

To attain Milestone 1, the RRPIC should have assessed:

— The national and local industrial capabilities;
— The interest of business and industrial leaders in participating in the research reactor project considering the special requirements necessary;
— The investments needed for upgrading domestic industrial facilities and programmes;
— The short term and long term policies needed to encourage the desired and realistic level of participation.

4.19. PROCUREMENT

Procurement of the research reactor and its ancillary facilities require a high degree of expertise in project management, safety management, research reactor operations and contract management. Without these skills, the owner/operating organization will not be able to respond to the technical and programmatic aspects of the research reactor project, and will not be able to validate that all design decisions are appropriate and safe, and as a consequence, would not be in a position to accept the prime responsibility for safety when the research reactor is commissioned.

Decisions on procurement are also related to the decisions on domestic industry involvement. The RRPIC should be aware of the unique requirements associated with purchasing equipment and services for nuclear facilities.

The RRPIC should recognize the need for:

— A procurement policy consistent with the industrial participation policy;
— Assembling specific project management, contracting and technical expertise prior to development of the bid specification;
— Regulatory involvement in the procurement process through development of the appropriate regulations and expertise.

5. MILESTONE 2: READY TO INVITE BIDS FOR THE RESEARCH REACTOR

Following the policy decision to proceed with the development of a research reactor project, substantive work for achieving the necessary level of technical and institutional competence should be undertaken. This second phase requires a significant and continuing commitment from the government and from the operating organization. It is assumed that the duties of the RRPIC will be incorporated into the regulatory authority at this stage of the project.

During the second phase of the programme, the State will carry out the work required to prepare for the construction of a research reactor. The nuclear legislation will need to be enacted before proceeding with a request for bid for the first research reactor. The regulatory body will need to be developed to a level at which it can fulfil all of its oversight duties. Before the commencement of the bidding process, the licensing stages and activities to be licensed should be defined, including safety and security requirements for the bidding process itself. The necessary infrastructure should be developed to the point of complete readiness to request a bid or enter into a commercial contract. This publication assumes that the State may use the competitive bid process to purchase the first research reactor; however it is acknowledged that there are a number of different procurement processes for the acquisition of the first reactor, including securing the supply of necessary nuclear fuel.

An effective management system and staff capabilities need to be developed to ensure proper accomplishment of the operating organization obligations. The operating organization has a key role at this time in ensuring that it has developed the competences to manage a nuclear project, to achieve the level of organization, operational culture, and safety culture necessary to meet the regulatory requirements, and the ability to demonstrate that it is an adequately informed and effective customer. IAEA Safety Requirements No. NS-R-4, Safety of Research Reactors and the IAEA Safety Guide No. NS-G-4.5, The Operating Organization, and the Recruitment, Training and Qualification of Personnel for Research Reactors provide useful guidance on how to establish an operating organization with a strong safety culture.

5.1. NATIONAL POSITION

The transition from the policy decision to develop a research reactor project to being ready to initiate the project requires the continued support and involvement of the government. It is the government’s responsibility to establish the necessary legal framework and to ensure that there is technical and institutional competence to construct and operate a research reactor.

These responsibilities are best fulfilled by creating the appropriate independent organizations. The government investment in nuclear infrastructure is essential and likely to be much larger than the cost of the research reactor.

During Phase 2 it is expected that the government will:

- Enact appropriate legislation, adopt the relevant international legal instruments, and continue participation in the Global Nuclear Safety Regime (INSAG-21);
- Provide the support and resources for timely infrastructure development;
- Recognize the need for national (technical support organizations, advisory bodies, etc.) and international support, and arrangements to ensure their independence;
- Establish a competent and effectively independent regulatory body responsible for safety and nuclear security (or expand the existing regulatory body) to license and regulate the design and operation of the research reactor, and provide it with adequate authority, staffing, equipment/tools and financial resources;
- Establish the financial and operational modalities for the ownership and operation of the research reactor;
- Establish the policy for nuclear fuel management, including replacement fresh fuel supply, if needed, and spent nuclear fuel and radioactive waste management;
- Establish the legal, organizational and financial arrangements for nuclear liability, decommissioning and radioactive waste management;
- Ensure stakeholder involvement in the research reactor project;

- Establish a policy for national and industrial participation in the research reactor project and initiated programmes for the human and physical resources development to implement the policy;
- Ensure that the programmes for national safeguards for nuclear materials and an effective SSAC, are developed, established, and implemented;
- Ensure that programmes for physical protection of nuclear materials and facilities are developed, established, and implemented;
- Ensure programmes for radiation protection and emergency planning are established, and implemented;
- Ensure that international standards for environmental protection are adopted developed, established and implemented in the country.

Accomplishing these conditions will provide a credible basis for requesting a bid for the first research reactor.

5.2. NUCLEAR SAFETY

The prime responsibility for safety rests with the operating organization. This requires that the operating organization is technically competent to understand all design features of the research reactor and its ancillary facilities, the nuclear and conventional safety risks that they present, and how to effectively manage those risks. In turn, this will require that the operating organization is involved in the development of the bid specification(s) for the project, and with the supervision of the design and construction phases. The operating organization must have access to sufficient technical expertise and experience to effectively manage these issues.

In addition, all efforts should be taken to ensure that an adequate level of safety awareness and the acceptance of personal responsibility for safety are achieved by all participants in the nuclear project. This includes the government representatives, vendors, operating organization, regulators (including technical support organizations) and other stakeholders.

Once the decision to embark on a research reactor project is made, the usual implementation process for large scale investment projects will be initiated. All of the relevant organizations should have an in-depth understanding of technical requirements and principles applicable to the design of research reactors. The operating organization should conduct a market survey on the research reactor technologies and their safety features that can meet the proposed stakeholder needs.

The first research reactor of a country most likely will be supplied by a foreign vendor. It is in the best interest of the purchasing country to obtain the agreement of the vendor country to continuously support nuclear safety. However, the decision making process for a research reactor is, in comparison to non-nuclear projects, complicated by a number of additional nuclear safety considerations specific to its construction.

During Phase 2, the type and size of the research reactor and the associated experimental facilities will be determined. The safety assessment should demonstrate compliance with the relevant safety requirements. The radiological safety assessment, which is carried out at this time to support the site selection, will be based on information from the safety assessment. Therefore, it is essential that the operating organization and the regulatory body (and technical support organizations, as appropriate) develops the expertise to conduct or review the safety assessment.

The government is responsible for establishing an independent, competent and effective regulatory body with sufficient knowledge to evaluate advice and submissions and to make safety decisions. The regulatory body should prepare and enact national safety regulations necessary for the bid specifications. IAEA Safety Standards and the Code of Conduct on the Safety of research reactors provide requirements (and guidance to achieve these requirements) on all aspects of the research reactor project.

5.3. MANAGEMENT

To achieve Milestone 2, the operating organization should have been designated and have assumed the responsibility for the development and implementation of the research reactor. The operating organization functions should be independent of the regulatory establishment.

During Phase 2, the operating organization should:

- Increase its staff and its competence as appropriate to prepare for bid specification development and evaluation;
- Begin formal training of staff in order to create a safety, nuclear security, and quality culture;
- Identify and ensure compliance with regulatory and safeguards requirements;
- Develop bid evaluation criteria, contracting strategy and supporting financing strategy;
- Develop a fuel supply strategy;
- Establish spent fuel and radioactive waste management programmes;
- Establish a working relationship with the regulatory body;
- Produce a project plan for the research reactor project, and communicate this plan to the regulatory body and government;
- Appoint a risk committee to consider technical, financial, political and environmental risks. The risk committee must be composed of a recognized experienced risk auditor, project and other staff experts in each of the mentioned areas and a senior corporate staff who will regularly interface with the research reactor project team. The timing of the appointment depends on the perceived emergence of significant risk. The risk committee needs to hold regular meetings to identify risks, record the level and likelihood of each risk, nominate persons to develop a response/mitigation strategy, and consider wider implications, with assurance that resources to deal with these risks are identified and obtained.

5.4. FUNDING AND FINANCING

Obtaining financing for a research reactor is a complex undertaking and developing a successful plan to obtain such financing will require significant expertise. Construction delays, regulatory delays and delays because of public intervention bring the risk of significantly increased cost.

A sound financing plan is also necessary to attract vendor interest to bid on the research reactor.

The strategies for funding and financing developed during Phase 1 should have evolved into firm actions and plans as follows:

- Strong public, stakeholder and government support for the research reactor project including commitments to fund operation and decommissioning;
- Funding mechanisms and guarantees established for the construction, operation, maintenance, waste disposal, and decommissioning;
- Funding for a complete legal framework supportive of the peaceful use of nuclear technology and of any financial guarantees necessary to support the research reactor project;
- Guaranteed funding to enable the regulatory body to fulfil its responsibilities;
- Fully funded safeguards programmes;
- The cost of creation of a competent operating staff manage, operate and maintain the research reactor;
- The costs of operations, maintenance, safety and security of the research reactor.

5.5. LEGISLATIVE FRAMEWORK

At Milestone 2, All legislation dealing with the research reactor project and the financial provision for the associated waste management and decommissioning costs must have been developed, promulgated and be in force prior to proceeding with a request for bids. This includes legislation to:

- Meet the non-proliferation undertakings of the Member State;
- Specify the allowed ownership of nuclear facilities and nuclear materials;
- Establish clear responsibilities and liabilities for the safe and secure operation of nuclear facilities and the handling and safeguarding of nuclear materials;
- Establishing an effective, independent regulatory body with full authority to discharge its responsibilities;

— Protect foreign investment and intellectual property;
— Provide funding or guarantees;
— Fund human resource development.

5.6. REGULATORY FRAMEWORK

At Milestone 2 the regulatory body must be fully established, competently staffed, and its scope of authority defined. The regulator should have a defined management system and formal training programmes for staff to create a safety, safeguards and nuclear security, and quality culture appropriate for the licensing and oversight of nuclear facilities. It should have arrangements in place for independent technical advice and resources as needed, with a focus on the consideration of safety and security issues. During Phase 2, the entire licensing process should have been developed and publicized so it is clear to all stakeholders. The regulatory criteria for siting, construction, design acceptance and approval of the research reactor should have been determined.

Mechanisms should have been established for open communications between the regulator and the operating organization. Such mechanisms must be transparent so that the independence of the regulatory body is evident. The relation between the regulatory body and the operating organization should be based on mutual understanding and respect as well as a frank and open communication, bearing in mind that the prime responsibility for safety, safeguards, and nuclear security is assigned to the operating organization and the primary role of the regulatory body is to ensure that the operating organization fulfils this responsibility.

At this stage of development, the priority issues for regulatory attention are:

— Overall organization, staffing and training of the operator and supporting organizations;
— Safeguards;
— Security;
— Nuclear and radioactive materials transportation, handling and storage;
— Radiation protection;
— Formal licensing process, including format and content of documents to be submitted to support licence applications;
— Regulations, codes and standards for site selection, design, construction, commissioning, operation and decommissioning necessary for licensing a research reactor, including the management system;
— Emergency preparedness requirements (site, off-site, and national, as necessary);
— Spent fuel and waste management, including disposal considerations;
— Access to independent and competent technical support;
— Establishment of international relationships with other regulatory bodies.

The regulatory approach should be appropriate to the nature, size and scope of the planned facilities, and consistent with IAEA Safety Standards and Nuclear Security Series Guidance. At Milestone 2, appropriate regulations, codes and standards are in force for:

— The import/export, transportation, storage and handling of nuclear and radioactive material;
— Radiation protection;
— Site environmental assessment and licensing;
— Research reactor site selection, design, construction, commissioning, operation, utilization and modifications, and decommissioning;
— Security and safeguards;
— Waste management;
— Emergency planning.

To reach Milestone 2, competent staff should be in place to:

— Review, and assess the licence application for the research reactor and its ancillary facilities, including siting, design, operating procedures, etc.;

- Develop programmes for the inspection and oversight of nuclear construction;
- Develop requirements for operator certification;
- Prepare for operational inspection and oversight.

5.7. SAFEGUARDS

In the preliminary stages of the development of a first research reactor project, the primary objective of the SSAC staff would be to provide information to the IAEA and implement safeguards-relevant activities in accordance with the applicable safeguards agreement(s). An example of such an activity would be the early provision of design information to the IAEA following the decision to proceed with the research reactor project.

As the research reactor project develops, the organization and functional specification of the SSAC should be adjusted as needed to ensure that the State is able to continue to fulfil its safeguards obligations. A robust domestic safeguards system is the cornerstone upon which international safeguards is built. The government should ensure that its national legislation is consistent with the terms of all of its international and/or regional obligations.

A State should provide early information to the IAEA on its plans related to the nuclear fuel cycle, research efforts, locations where nuclear materials may be used, and the export and import of nuclear materials and nuclear related items subject to the relevant safeguards instruments or Nuclear Supplier Group guidelines. Guidelines and training have been developed by the IAEA to assist the State in these matters.

The State will likely need to prepare relevant safeguards specific legislation, rules, regulations and procedures, depending on its policy decisions relating to the research reactor project and supporting infrastructure and the nature of the State’s existing legislation, rules, regulations and procedures. For example, import-export controls may need to be adjusted or established. Organizations and programmes for the effective implementation and enforcement of such legislation should be planned prior to requesting a bid for the research reactor.

5.8. RADIATION PROTECTION

Although the radiation hazards associated with research reactor operation will not be present for some time, adequate preparations for protection programmes are required to attain Milestone 2, including:

- Existing laws governing radiation protection have been reviewed and any enhanced legislation needed;
- Specific radiation protection regulations appropriate for research reactors have been developed by the regulatory body;
- The operating organization has plans for worker, public and environmental monitoring and protection.

5.9. RESEARCH REACTOR UTILIZATION

Early in Phase 2, the AMPT and the operating organization should review the utilization plans from Phase 1, and consider how best to implement these organizationally and managerially when the research reactor is operational. It should also develop appropriate technical specifications for the reactor and its ancillary facilities. While most of the responsibility for defining the utilization of the research reactor will be assumed by the operating organization, it is important that the stakeholder and user communities are consulted and endorse the performance specifications of both the research reactor and ancillary facilities.

To achieve Milestone 2, the operating organization should:

- Establish stakeholder interaction groups to help define the specifications of the research reactor and ancillary facilities;
- Access the experience of the regional and international research reactor communities to fully understand the resource and funding requirements of the proposed utilization;
- Develop a detailed Utilization Plan for the research reactor project. The Utilization Plan should include facility, resource, and personnel development;

— Work with the AMPT to draft the technical and operating requirements specification for the research reactor bid invitation, consistent with the Utilization Plan and the resource and funding availability.

5.10. HUMAN RESOURCE DEVELOPMENT

To be ready to invite bids for the research reactor and its ancillary facilities, core human resources need to be in place. Competent staff with knowledge of the specific technologies involved in the research reactor project are required to prepare the bid specification and evaluation criteria; to evaluate bids from a technical, management, business and economic perspective; and to manage the subsequent contract implementation and design development. Key staff skills required at this stage of the research reactor project include project management of technically complex projects, safety and licensing of nuclear facilities, operations and maintenance of research reactors and the selected ancillary facilities, and contract management.

The existence of a well qualified regulatory staff is of fundamental importance in developing regulations, codes and standards according to which the research reactor will be licensed. Milestone 2 requires the applicable regulations to be complete and in force. Participation of the regulatory body staff in inspections of similar installations in other countries is a good practice.

Licensed operators and maintenance technicians are not needed for Milestone 2. However, the initial operational and maintenance requirements should have been drafted. Initial education and training for the remaining resources to fully support research reactor operation should begin at this time. It is important that staff trained and knowledgeable in quality assurance principles is available in both the regulatory and operating organizations.

Specific human resource development criteria for Milestone 2 include:

— Business, technical and project management expertise to develop the bid specification and evaluation criteria, select and contract with the vendor, manage contract implementation and design development;
— Business and technical expertise for fuel cycle procurement and management;
— Technical and scientific expertise for site qualification and preparation of licence applications;
— Political and social expertise for public communication;
— Technical and regulatory expertise to develop and implement regulations, codes and standards for facility licensing, site approval, operator licensing, radiation protection, safeguards, physical protection, emergency planning, waste management, and decommissioning;
— Plans to fully staff and train operating, maintenance and support organizations;
— Plans to develop future expertise in all relevant areas, including any needed enhancements to national educational institutions and facilities.

5.11. STAKEHOLDER INVOLVEMENT

The AMPT and the government began the process for gaining and maintaining political and public support in the initial phase of the project. Other organizations should join the effort as they are created. The regulatory body and the operating organization should develop public information and education programmes and engage in public dialogue as they form and begin to exercise their responsibilities. Effective public communication is a skilled discipline and those involved should receive professional training.

The appropriate conditions to be established for each organization are:

— The government should continue to communicate the reasons for and expected benefits of the research reactor and remain responsive to expressions of concern as the implementation moves forward;
— The regulatory body should explain its independent role in licensing and inspecting all nuclear activities to assure compliance with safety and nuclear security regulations and standards;
— The regulatory body should decide upon and communicate the formal process for public participation in the licensing process and should declare its openness to public participation;

- The operating organization should explain the basic technology being employed and the plans for construction activities;
- All organizations should openly discuss problems and difficulties encountered and the plans to successfully resolve them;
- All organizations should communicate with one another in a transparent and professional manner demonstrating understanding and respect for their respective roles.

The potential users of the research reactor and customers of its products and services should be consulted during the drafting of the technical specifications for the reactor and its ancillary facilities. The user community contributes significantly to the robustness and the credibility of a research reactor project by advocating the programme to national and international stakeholders and by providing a continuous monitoring and assessment of the programme efficiency in terms of flexibility, quality of the service, cost effectiveness, etc. User community endorsement of the specifications for the research reactor and its ancillary facilities is a condition of Milestone 2.

5.12. SITE SURVEY, SITE SELECTION AND EVALUATION

A detailed site characterization should be completed for one or more sites that meet the national criteria for nuclear facility application. The important steps that should be taken to achieve Milestone 2 are:

- Regulatory requirements for site evaluation have been issued;
- One or more suitable sites have been selected and carefully characterized, and the site(s) have been secured to assure their availability and integrity;
- Local legal, political and public acceptance issues have been identified and resolutions implemented or planned;
- Appropriate site(s) characteristics have been included in the bid specification;
- Necessary improvements or upgrades to local infrastructure such as site(s) access, services and facilities have been identified and planned;
- Environmental monitoring has been initiated to establish the monitoring baseline;
- A site evaluation report has been prepared and submitted to the regulatory body.

5.13. ENVIRONMENTAL PROTECTION

At Milestone 2, the environmental characteristics of the potential sites for the research reactor and its ancillary facilities should be known and the specific challenges for environmental monitoring at the chosen site identified. Plans to resolve these challenges are being developed including identification of design or construction provisions to address them.

Environmental studies should be performed for each of the potential sites for research reactor facilities to ensure that environmental laws and regulations can be met. Any particular environmental sensitivities that are identified by the studies should be addressed in the bid specification to ensure that they are addressed during reactor design and construction.

Issues for consideration include:

- Pathways for effluent transport and concentration in the surrounding environment;
- Predominant plant and animal life and their particular sensitivities;
- Local population demographics and trends;
- Predominant land use;
- Water use;
- Impacts of construction activities on the local environment.

5.14. EMERGENCY PREPAREDNESS AND RESPONSE

During Phase 2, detailed emergency planning began at the time of site selection, though not all implementation details need to be in place to achieve Milestone 2. Emergency plans should consider both the research reactor facilities and the surrounding community. Issues of importance include:

- Basic regulations requiring emergency planning have been developed;
- Procedures for protecting emergency workers have been formulated;
- Procedures for provisions for public notification, information and instructions have been considered as part of the site selection;
- Options for sheltering and public evacuation have been considered according to the potential hazard of the planned research reactor, and any impediments identified;
- Procedures to deal with non-radiological consequences have been considered;
- Necessary agreements for local and national authority participation have been identified and preliminary discussions have been held.

5.15. NUCLEAR SECURITY

To achieve Milestone 2, the following conditions should be met:

- An effective national legislative and regulatory framework to regulate nuclear security has been established, including:
- Assessment of what risk (consequences combined with probability) from a malicious act is unacceptable, and what level of effort is needed to protect against such an act, given the resources availability, the benefit of the asset to society, and other priorities;
- Definition and assignments of security responsibilities to relevant entities including the independent regulatory body;
- The statement that prime responsibility for implementing and maintaining nuclear security measures resides with the operator;
- Establishment of the authorization process. As appropriate, the authorization process concerning nuclear security could be integrated within one defined for safety or radiation protection;
- Establishment of the inspection process for nuclear security requirements;
- Establishment of the enforcement process for the failure to comply with nuclear security requirements;
- Establishment of defences against the unauthorized removal of radioactive material from, and sabotage of, the research reactor and its ancillary facilities;
- Establishment of information protection mechanisms to prevent unauthorized disclosure of information that could compromise the protection of radioactive material or the research reactor. This should include measures to ensure the trustworthiness of persons with authorized access to sensitive information or, as applicable, to radioactive material and the research reactor;
- A threat evaluation for radioactive material and the research reactor, which the regulatory body should use as a common basis for determining nuclear security requirements;
- Inclusion of security considerations in the bid specification.

5.16. NUCLEAR FUEL MANAGEMENT

During Phase 2, the operating organization should develop a fuel management strategy as an input for the bid invitation. This strategy will include the arrangements for obtaining replacement fuel, if needed, and the management and disposition of spent fuel. A decision as to whether replacement fuel should be included in the contract for building the research reactor needs to be taken at this time, and a specification developed for the required spent fuel storage capacity.

The following are conditions to attain Milestone 2:

— Decisions have been taken regarding:
— Which fuel to purchase with the research reactor, including both the initial reactor fuel, and any replacement fuel deemed appropriate;
— Whether to purchase or develop indigenously specific fuel cycle services;
— The on-site spent fuel storage capacity to be contracted with the research reactor;
— Mechanisms are identified for the purchase of subsequent replacement fresh fuel, if needed;
— The policy for final disposition of spent fuel or its resulting radioactive wastes has been defined, and the national facilities for dispositino of spent fuel, or the radioactive wastes obtained from processing the spent fuel has been evaluated, costed, and the financing mechanisms established.

5.17. RADIOACTIVE WASTE

The burdens of radioactive waste disposal from research reactor operation will not be encountered for several years. However, during Phase 2, early activities related to radioactive waste include:

— Revising the laws and regulations associated with low and intermediate radioactive waste disposal;
— Formulating the radioactive waste management strategy and establishing a responsible organizationorganization and funding system;
— Consideration by the operating organization of the arrangements for safe management of radioactive waste, including that generated from facility decommissioning;
— Developing provisions for waste volume and toxicity minimization as part of the bid specification.

IAEA Safety Standards Series No. NS-R-4 establishes the requirements for safety of radioactive waste and decommissioning for research reactors, and IAEA Safety Standards Series No. NS-R-5 provides general safety requirements on safety of radioactive waste management, spent fuel and decommissioning. IAEA Safety Guide No. NS-G-4.6 provides guidance on the radioactive waste management in the design of research reactors, and guidance and recommendations on establishing an operational radioactive waste management programme for research reactors.

5.18. INDUSTRIAL INVOLVEMENT

National and local capabilities to supply commodities, components and services for nuclear facility construction should be reviewed by the AMPT. The ability to meet schedule and quality requirements will be crucial to successful construction of the research reactor on time and within budget.

At this stage the AMPT should consider:

— Which national or local suppliers can reliably supply commodities, components or services to nuclear related or non-nuclear portions of the facility to be constructed;
— What upgrades in skills and capabilities are realistic in a time frame to support research reactor construction;
— Firm decisions on national or foreign sources of supply for commodities, components and services for the first research reactor;
— Ensuring that the bid specification is in accordance with those decisions.

5.19. PROCUREMENT

The operating organization should establish a procurement programme consistent with the national policy for industrial participation and procurement and ensure that it is competently staffed to manage the procurement process.

For Milestone 2, the operating organization should:

- Develop programmes and procedures that meet the established requirements;
- Develop formal procurement specifications and approved vendor lists;
- Ensure that quality standards are in the bid package, with the right for the operating organization or its representatives to visit vendor shops to verify compliance of critical components to these standards;
- Ensure that is has experienced project and contract managers to control the procurement process.

6. MILESTONE 3: READY TO COMMISSION AND OPERATE THE RESEARCH REACTOR AND ITS ANCILLARY FACILITIES

The third phase of the programme development consists of all the activities necessary to implement the first research reactor and complete most of the infrastructure development. During this phase, the greatest capital expenditures will occur. Attention by all organizations is crucial to the successful outcome and all have important roles to play.

At the end of this phase, the operating organization will have developed from an organization capable of ordering a research reactor to an organization that can accept responsibility for commissioning[4] and operating one. Procedures and arrangements to ensure safe control of research reactor under all conditions will have been developed as well as significant development and training for all levels of staff.

While achieving the third milestone is a major accomplishment, it should be remembered that it is only the beginning of a lasting commitment to the safe, secure and effective utilization of the research reactor.

6.1. NATIONAL POSITION

- To attain Milestone 3, the government must have established the infrastructure to license, regulate and safely commission and operate the research reactor consistent with international standards and commitments. It should have monitored the development of the organizations and institutions responsible for the construction, operation and regulation of the facilities and ensured that they are competent. In summary, the government should have ensured:
- That all appropriate laws and regulations remain in place and the responsibility for compliance has been clearly designated;
- That there are adequate funds and resources for the protection of materials and facilities;
- That regulatory body is fully funded, staffed with competent and trained personnel, and provided with the necessary facilities and resources; and that it has assumed its responsibilities and functions with full authority;
- That the regulatory body has confirmed the technical and management competence of the operating organization;
- That the advice of support organizations (technical support organizations, advisory bodies, etc.) is independent of the operator and of any nuclear promotion considerations;
- That stakeholder involvement and satisfaction remain priorities;
- That financing is sufficient to sustain the safe operation of the research reactor and its facilities, and financing mechanisms have been established for the eventual decomissioning of the research reactor and related facilities, management of spent fuel and radioactive wastes, and for compensation of nuclear damage;

[4] In the context of this publication, the commissioning process is assumed to start before fuel is delivered to the facility.

— Continued participation in international activities and networks, including a strong cooperation programme with the Supplier's country, if applicable;
— That the human and physical resource development programmes are appropriate to support the continued safe operation of all nuclear facilities.

6.2. NUCLEAR SAFETY

Safety issues are intrinsic to every aspect of a research reactor project. An effective system of safety regulation and supervision must be in place at Milestone 3 to cover commissioning, operation, utilization and facility modifications, decommissioning and management of spent fuel and other radioactive waste. The operating organization as well as the regulatory body and its technical support organizations must have developed a safety culture. The IAEA Safety Standards are appropriate references to assess whether good international safety practices are in place. The regulatory body should be sufficiently prepared at this time and have the authority to determine whether an adequate appreciation for safety is present and to take appropriate measures if not.

To attain Milestone 3, the operating organization should:

— Maintain knowledge of the design and construction (configuration management) during the lifetime of the facility and ensure that 'as-built' drawings and safety documents are maintained;
— Ensure adequate safety review and assessment of the facility design and implementation;
— Prepare with the supplier, and provide the Safety Analysis Report, commissioning programme, operating limits and controls, emergency plans, etc. for the research reactor;
— Develop all necessery operation management programmes (including operating procedures and maintenance programme), in accordance with the IAEA Safety Requirements No. NS-R-4, and submit them to the regulatory body, as required;
— Adhere to the Research Reactor Safety Requirements, IAEA Safety Standards Series No. NS-R-4 and Commissioning of Research Reactors Safety Guide, IAEA Safety Standards Series No. NS-G-4.1.

The regulatory body should review all safety documents to ensure compliance with regulatory and safety requirements.

The operating organization and the regulatory body should:

— Ensure that an effective management system is in place at all times during construction;
— Ensure that the process to address changes in the design during construction and document the configuration changes is adequate;
— Establish periodic safety review mechanisms to deal with the cumulative effects of reactor ageing, modifications, changes in utilization, installation of new experimental devices, operating experince, and changes in regulatory requirements or development of safety stadards throughout the research reactor lifetime. [5]

6.3. MANAGEMENT

The government, through its authorised agencies, should lead the national planning for waste disposal and decommissioning.

[5] Guidance on performing safety assessment and preparation of the Safety Analysis Report for research reactors are provided in the IAEA Safety Guide No. 35-G1. Recommendations for achiveing safety in research reactor utilization and modifications are provided in the IAEA Safety Guide No. 35-G2, and guidance on performing periodic safety review for research reactors can be found in the IAEA Safety Guide No. SSG-10 on ageing management of research reactors.

The independent regulatory body should have the management systems required for:

— Making decisions that affect nuclear safety, nuclear security, protection of the public and environment;
— Continuing staff and competence development;
— Conducting environmental, safety, and security, reviews of the proposed research reactor;
— Establish and implement a regulatory inspection programme;
— Continuing to interact with internal and external stakeholders in a transparent manner so that the independence of the regulator is evident.

During Phase 3, the operating organization should have established the Safety Committee to support and advise the operating organization, throughout the lifetime of the research reactor, as required by IAEA Safety Requirements No. NS-R-4. It should also have established training and certification programmes to maintain the operation and maintenance staff for the reactor and its ancillary facilities, and established mechanisms for external operational, training, engineering and maintenance support. Key to sustaining high levels of staff performance are the establishment of clear performance expectations (indicators) and assessment of the extent to which these expectations (indicators) are achieved, and providing incentives for achieving performance indicators.

The operating organization should continue promoting open communication and effective interactions with the research reactor supplier and regulatory body. The research reactor project schedule should be developed in such a way to allow the operating organization to effectively interact at all stages of the research reactor project development, including the basic and detailed design reviews. The project schedule should also include 'holding points' for regulatory review and assessment, including a defined schedule for submitting the necessary documents. The operating organization should establish arrangements with the designer for provision of a support from the designer technical staff in the discussions with the regulatory body.

Achievement of Milestone 3 requires that the operating organization is capable of assuming full responsibility for the safe and efficient operation of the nuclear facility in accordance with IAEA Safety Standards.

Effective interactions between the operating organization and regulatory body should continue to be promoted during the operation of the research reactor, to draw the operational feedback of events, discuss and anticipate major modifications (new utilization or programmes of the reactor, major equipment modifications, preparation of safety and security reviews, etc.). Some of these interactions shall be formally defined in the operating license conditions.

6.4. FUNDING AND FINANCING

During Phase 3, the operating organization should obtain adequate financing consistent with the financing strategy and the contract. To attain Milestone 3:

— Financial mechanisms must be in place to cover the facilities' operation and maintenance (e.g. staff salaries, electricity and other utilities, procurement of nuclear fuel, targets for isotope production, etc.) as well as for decommissioning, and long term spent fuel and waste management;
— Funding of appropriate human and physical facilities development and legislative support continues, as necessary.

6.5. LEGISLATIVE FRAMEWORK

To attain Milestone 3, the legislative framework should have been maintained and amended as necessary during the lifetime of the research reactor project.

6.6. REGULATORY FRAMEWORK

During Phase 3, all regulations, codes and standards for construction of a research reactor and its ancillary facilities were put in place, with sufficient staffing for the effective review and licensing of nuclear facilities. To attain Milestone 3, the selected regulatory approach must be fully implemented and the regulatory body remain competent in all aspects of nuclear licensing and oversight. Regulatory requirements have been established for research reactor operator training and certification.

Plans to maintain competent regulatory staff and to develop future staff should be in place, and the regulator has opened communications with the government, the operating organization and the public. International and professional interfaces are being maintained.

Prior to nuclear fuel loading, the regulatory body should issue the licenses[6] required for commissioning of a research reactor. Successful commissioning is the basis for the operating license of the reactor. The staff should be in place and fully competent to review and oversee the commissioning, operation, maintenance, utilization, and modifications processes of the reactor in accordance with formally established programmes.

Regulatory inspections will have begun during the site preparation and construction stages in Phase 3, and will become more intensive during the commissioning and operation stages. These inspections should aim at verifying that the research reactor and associated activities comply with the latest approved safety, safeguards, and security documentation (SAR, Operational Limits and Conditions, emergency plan, radiation protection programme, etc.). The regulatory body may perform inspections at short notice if abnormal occurrences warrant immediate investigation.

At the end of Phase 3, the regulatory body has confirmed that the licensee has demonstrated compliance with the relevant regulatory requirements.

6.7. SAFEGUARDS

Safeguards issues are intrinsic to every aspect of a research reactor project from the outset. Safeguards measures are applied to all nuclear material, and as appropriate to nuclear-relevant activities and facilities under the control or jurisdiction of the State. To attain Milestone 3:

— National legislation and regulation on safeguards must clearly identify the nuclear activities, installations, facilities, locations and material to which safeguards will be applied;
— All elements of the safeguards infrastructure, including the SSAC and trained and appropriately equipped staff in the operating organization should be in place and a process for effectively maintaining them, prior to the receipt of the initial nuclear material for the research reactor;
— Information regarding all relevant nuclear material subject to safeguards instruments has been provided to the IAEA;
— The facility specific details of agreements with the IAEA have been put in place, and any on site pre-startup design verification activities have been completed.

6.8. RADIATION PROTECTION

All radiation protection programmes must be implemented before the first radioactive material arrives on site. The conditions necessary to meet Milestone 3 include:

— Radiation monitoring equipment in place and operational both on and off-site;
— The site environmental monitoring programme is fully implemented;
— Off-site radiation monitoring programmes are underway;
— Radiation dosimetry requirements are in place for all workers;
— Programmes to minimize radiation exposure during research reactor operation and maintenance have been developed;
— Radiation protection plans have been prepared and tested through exercises. and associated training programmes completed.

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[6] Some Member States refer to a licence as an ‘ermit’ or ‘authorization’.

6.9. RESEARCH REACTOR UTILIZATION

During Phase 3, the operating organization should have established an effective relationship with the design authority, and ensured that the utilization requirements for the research reactor project were adequately addressed. This is one of the most important relationships in the design phase of the research reactor as it will have a large influence on the subsequent ability of the operating organization to meet the expectations of Government, stakeholders and the stakeholder communities.

At Milestone 3, the operating organization should have:

- Effective interaction with the design authority;
- Implemented knowledge and technology transfer programmes;
- Reviewed the detailed design of the ancillary facilities and equipment;
- Ensured the development of personnel, and infrastructure needed for effective utilization of the research reactor;
- Procured equipment and other resources for the planned utilization programmes;
- Effective interaction with stakeholders and stakeholder groups;
- Developed detailed operational plans for each of the areas identified in the Utilization Plan, which may include calling for research proposals, and negotiating supply contracts with customers;
- Developed commissioning procedures;
- Effective interaction with the regulator, seeking the necessary authorizations or approvals;
- Developed a marketing plan for the research reactor project;
- Investigated the potential for strategic partnerships with other research, industrial, and commercial organizations.

6.10. HUMAN RESOURCE DEVELOPMENT

At Milestone 3, all of the human resources should be in place. Educational and training programmes to ensure a continuing availability of qualified people for all activities associated with the research reactor project should be well underway.

Specific human resource requirements at this time include:

- Fully staffed research reactor operation, maintenance and technical support groups, with licensed or certified, as appropriate, operation and maintenance personnel for both the reactor and its ancillary facilities;
- A full staffed regulatory body with specific expertise in oversight of research reactor commissioning and operations;
- Succession and personnel development planning to sustain the competence of all areas of the research reactor project;
- Advanced educational opportunities for nuclear science and technology;
- Training programmes for operator and technician development.

Well before the end of Phase 3, the operating organization should have completed the process of selection and recruitment of the research reactor operating personnel. The training programme on research reactor operation, maintenance, and systems turnover should start in this phase, in conjunction with all parties involved in the research reactor project, including the supplier. This will facilitate participation of the operating personnel in the commissioning activities as a part of their on the job training.

It has to be recognized that different cultural and managerial styles of managers, engineers and scientists will exist. These differences may lead to communication issues and may make it difficult to align goals and establish priorities. A prerequisite for establishing a good safety and nuclear security culture is good communication across interfaces. It is recommended to hold specific training sessions, including the relevant project officers, to address this potential problem.

The maintenance of competencies is a major concern in terms of safety and security impacts throughout the lifetime of the installations.

6.11. STAKEHOLDER INVOLVEMENT

By the start of construction of the research reactor, each of the organizations involved should have established reasonable credibility with the stakeholders and the public. The communication efforts should have been maintained throughout the construction and preparation for operation.

The appropriate conditions to be established for each organization are:

- The operating organization should continue to explain its rationale for introducing the research reactor project, addressing the balance of benefits and costs/risks considered;
- The regulator should continue to communicate the progress of the licensing process and the planned operational inspection programme;
- The regulator should provide opportunities for appropriate public involvement in the licensing and inspection process in strict compliance with the formal process adopted and previously explained;
- The operating organization should have routinely consulted with the stakeholders, and communicated the progress of the construction programme, and design amendments, and the preparations for operation;
- All organizations should continue to openly discuss problems and difficulties encountered and their resolutions;
- All organizations should continue to interact with one another in a transparent and professional manner.

6.12. SITE SURVEY, SITE SELECTION AND EVALUATION

At an early stage of Phase 3, the operating organization should submit to the regulatory body a site evaluation report which includes updated environmental impact assessment, taking into account all the characteristics of the site, safety, and security features of the design. Also, at an early stage of Phase 3, stakeholder agreement should be obtained regarding the site selection. The regulatory body should review and asses the submitted reports and conclude acceptability of the site according to the national licensing process.

By the time the first fuel arrives on the selected site:

- All site services must be in place and functional;
- All site safety, safeguards, and security must be in place;
- All site environmental monitoring must be underway.

6.13. ENVIRONMENTAL PROTECTION

Assurance that the environmental laws and regulations will be complied with should have been accomplished as part of the licensing process for the site and the research reactor. Programmes for monitoring and assessment should be fully implemented.

A survey programme around the research reactor site should be started well before commissioning of the research reactor in order to obtain reference data on radioactive isotopes found in the environment. This data can be used to identify the radioactive isotopes that may be released from the research reactor.

At Milestone 3, conditions that should have been established or are underway include:

- A formal environmental impact assessment has been completed;
- Specific environmental requirements have been identified, and included in the licensing conditions for facility operation;
- The site and its surroundings should have been completely characterized to define the baseline condition;
- Provisions for the storage, transport and disposal of waste are in place;
- Environmental monitoring programmes have been developed and are fully implemented in accordance with national and/or international standards.

6.14. EMERGENCY PREPAREDNESS AND RESPONSE

Before the first nuclear fuel arrives on site, all preparations for emergency response should be completed and tested. The necessary conditions to be established include:

- The threat assessments have been performed;
- Demographic characteristics of the selected site or sites have been studied;
- Plans for emergency response have been formulated, finalized into firm programmes and procedures and have been implemented;
- The regulatory body has reviewed and approved the emergency plans;
- Written protocols and procedures between the operating organization, local and national authorities and the regulatory body have been developed and are in place;
- Emergency notification systems are in place and thoroughly tested;
- Impediments to sheltering, evacuation, medical responses as iodine distribution etc., have been removed;
- Emergency drills and exercises have been run, with the participation of local and national organizations and demonstration to regulatory authority, to test and to assure the effectiveness of the emergency arrangements; evaluation and lessons learned from these drills have been incorporated into the emergency procedures and protocols.

6.15. NUCLEAR SECURITY

Security issues are intrinsic to every aspect of a research reactor project from the outset. An effective system of security regulation and supervision must be an integral part of the research reactor licensing process, the operating organization, regulatory body and related organizations must have adopted a security culture in order to attain Milestone 3. The regulatory body has the expertise and authority to determine whether an adequate appreciation for security is present and to take appropriate measures if not. The IAEA Nuclear Security Fundamentals and Nuclear Security Series guidance are appropriate references.

The following conditions for Milestone 3 also apply. The operating organization should:

- Ensure it maintains knowledge of the design and construction of the nuclear security system during the lifetime of the research reactor, including procedures for controlling, approving and documenting configuration changes;
- Ensure adequate security review of the design of the nuclear security system proposed by the vendor in the submitted bid, and work with the vendor to prepare the security plan;
- Establish contingency plans and develop arrangements and protocols between appropriate response organizations for the response to nuclear security events;
- Conduct regular joint exercises with the appropriate authorities to assess and validate contingency plans, to train the participants in how to react in a nuclear security event and to review contingency plans, as necessary. Joint exercises that simultaneously test emergency and contingency plans should also regularly carried out.

The regulatory body should have reviewed the security plan for compliance with regulatory and security requirements and ensured that an appropriate change control system is in place.

6.16. NUCLEAR FUEL MANAGEMENT

Steps should be taken during Phase 3 to ensure that adequate supplies of fuel are available for, and can be transported to, the research reactor. This may be addressed in the contract to purchase the reactor or may be a separate contracting activity.

Facilities to store spent fuel must be available at the start of reactor operation in order to ensure that the research reactor core can be unloaded into this storage capacity at any time.

In order to attain Milestone 3, the mechanisms for final management of the spent fuel must be prepared and financing mechanisms defined.

6.17. RADIOACTIVE WASTE

Low and intermediate radioactive waste will be generated as soon as the research reactor reaches critically. Milestone 3 requires that appropriate preparations and facilities are in place, including:

- A plan for disposal of all radioactive waste categories, including a preliminary decommissioning plan, and updates to the corresponding chapters of the Safety Analysis Report;
- Fully operational facilities for the processing and storage of low, intermediate and high level radioactive waste that are able to receive wastes from the research reactor;
- Full implementation of regulatory oversight of radioactive waste management facilities and regulatory body verification that the programme for radioactive waste management and the preliminary decommissioning plan comply with the regulatory requirements.

6.18. INDUSTRIAL INVOLVEMENT

As the construction phase of the research reactor project nears completion, a reassessment of the sources of supply to support operation can be undertaken. This includes the supply of spare parts, consumables, maintenance services and calibration services. The same careful supplier qualification is needed for operational support as for facility construction.

6.19. PROCUREMENT

During Phase 3, the operating organization will proceed with the task of constructing, licensing and preparing to commission and operate the research reactor, and should:

- Obtain adequate financing consistent with the financing strategy and the contract;
- Formally evaluate all bids and select the winning bid in accordance with the bid evaluation criteria;
- Negotiate the contract with a scope of supply consistent with the contracting strategy, including contract arrangements to obtain necessary technical, safety, and security documents according to a defined schedule for the different stages of the programme;
- Sign the contract for the research reactor;
- Obtain required licenses for construction;
- Ensure construction is complete and ready for commissioning;
- Obtain an operating license for the research reactor;
- Contract for a continuing fuel supply, if appropriate;
- Establish provisions for any needed external operational, training, engineering and maintenance support.

At Milestone 3, the operating organization has, or has access to, a procurement organization with the programmes and skills necessary for purchasing of nuclear related equipment and services.

7. CONCLUSIONS

A new research reactor that is appropriately conceived, managed, and supported is an extraordinary tool that contributes to a country's scientific resources, and helps raise living standards through improved health care and industrial and agricultural productivity. However, its construction and operation requires recognition of important international responsibilities, and a well defined and implemented policy and regulatory, safety and technical infrastructures. These include a legal framework, appropriate finances, human resources, and waste management resources. The regulation, operations, spent fuel and waste management aspects of the research reactor represent costs that will be incurred for several decades, and for which appropriate financing and governance mechanisms must be established at the outset.

Addressing these issues requires a systematic approach that starts with a careful justification for the research reactor. If the research reactor can be justified, and sufficient users and sponsors found to support its construction and operation, then the focus should move to reviewing and implementing the necessary infrastructure in addition to work on the research reactor itself. Three further phases of work can be identified each culminating in the achievement of milestones that demonstrate that the project is ready to move forward into its next phase.

By following this systematic approach to decision making, stakeholder engagement and project development, the research reactor project will be safe, secured and cost effective and able to achieve its full potential.

APPENDIX

SUMMARY OF CONDITIONS TO ACHIEVE THE MILESTONES

Infrastructure issue	Milestone 1 — Ready to make a knowledgeable commitment to a research reactor project	Milestone 2 — Ready to invite bids for the research reactor	Milestone 3 — Ready to commission and operate the research reactor and its ancillary facilities
(1) National position	• RRPIC established, staffed, authorized and funded; • Safety, security and non-proliferation needs recognized at the level of the government or its authorized agencies; • Requirements for participation in the Global Nuclear Safety Regime identified; • Appropriate international legal instruments identified; • Required intergovernmental agreements identified; • Government liabilities for radioactive waste management and decommissioning recognized.	• International legal instruments adopted; • Regulatory body established; • An effective SSAC established; • Policy for spent nuclear fuel management established; • Legal and financial arrangements for decommissioning established; • Human resources development programme started; • Safeguards programme provided; • Security programme provided; • International standards for environmental protection adopted; • Commitments and obligations of operator organizations established.	• Appropriate laws and regulations in place and responsibility for compliance designated; • Regulatory body fully funded and staffed; • Acceptable level of socio-political involvement maintained; • Financing assured for materials protection, and facility operation; • Financing mechanisms in place for waste, long term spent fuel management and decommissioning; • Advisory organizations independent from the reactor operator and from project promoters; • Human and physical resource development programmes in place.
(2) Nuclear safety	The importance of nuclear safety recognized including: • Application of the Code of Conduct on the Safety of Research Reactors; • Participation in the Global Nuclear Safety Regime; • Operator role as the primary responsibility for safety; • Accident prevention and mitigation; • Emergency preparedness and response.	• All stakeholders recognize their safety responsibilities; • The operating organization understands the issue of having the prime responsibility for safety; • Legal and governmental framework consistent with Fundamental Safety Principles implemented; • Safety culture evaluated; • Regulatory body able to evaluate the safety submission.	• The operating organization of the research reactor has assumed the primary responsibility on safety; • Safety culture adopted by the constructor, engineer, operating organization and regulatory body organizations; • Regulatory body prepared to determine whether an adequate appreciation for safety is present and with the authority to act independently; • Programmes to maintain technical skills and management attitude for a strong safety culture in place.
(3) Management	• AMPT established, and research reactor project organization and key roles defined; • Pre-project Assessment Report completed: • Siting options; • Consideration of ownership options and operational responsibilities; • Initial Strategic Plan prepared.	• Financial plan developed; • Safeguards procedures in place; • Strategic Plan updated; • Operating organization established with: o Adequate staff to manage site selection, bid preparation and bid evaluation; o Working relationships with regulatory body and international organizations; o Risk committee to consider technical, financial, political and environmental risks; o Research reactor project management team; o Knowledge management and technology transfer programmes; o Staff training started.	• Operating organization has: o The safety committee required by IAEA Safety Standards Series No. NS-R-4; o Working relationships with suppliers, the regulatory body, and reactor designer; o Good public communication; o Trained and certified operations staff; o Access to external operational, training, engineering and maintenance support; o Participated in all phases of research reactor design and construction; o Capability to assume full responsibility for the safe and efficient operation of the facilities.

Infrastructure issue	**Milestone 1 — Ready to make a knowledgeable commitment to a research reactor project**	**Milestone 2 — Ready to invite bids for the research reactor**	**Milestone 3 — Ready to commission and operate the research reactor and its ancillary facilities**
(4) Funding and financing	Funds provided for: • RRPIC review of the Pre-Project Report and Strategic Plan and of commitments required; • Drafting of nuclear legislation. RRPIC understands the funding and financing implications of: • Construction, operation and decommissioning of the research reactor, • Long term management of spent fuel and radioactive waste; • Creation of competent: o Operating staff; o Nuclear regulatory body; o Project management team; • Human resources development; • Security and safeguards arrangements.	• Funding and financing is provided for: o The design, construction, project management and regulatory oversight of the research reactor and supporting infrastructure; o Completion of the legal framework; • Means of funding and financing long term liabilities identified.	• Funding and financing mechanisms implemented for: o Long term spent fuel handling and final disposal; o Radioactive waste management; o Facility decommissioning.
(5) Legislative framework	• Nuclear legislative requirements identified by RRPIC and discussed with government; • Existing legislation reviewed for: o Radiation protection; o Radioactive waste management; o Transportation safety; • Government plans to amend or develop the required laws.	• All required nuclear legislation in force; • Meets the non-proliferation undertakings of the Member State; • Defines ownership of nuclear facilities and materials; • Defines responsibilities for safety, security and safeguards; • Establishes an independent regulatory body; • Laws protecting intellectual property, foreign investments, funding and guarantees in force.	• Legislation has been maintained and amended as necessary.
(6) Regulatory framework	• RRPIC understands the need for and the scope of the regulatory framework.	• Nuclear regulatory body established and staffed; • Licensing process developed; • Appropriate regulations, codes and standards developed; • Regulatory criteria for siting, design and commissioning established; • Mechanisms established for open communications between regulatory body and operating organization; • Consultant and expert services are planned.	• All nuclear regulations, codes and standards are in force; • A sufficient regulatory staff is in place; • Commissioning license has been issued; • Plant operators are certified; • Regulatory inspection and enforcement activities are in effect.
(7) Safeguards	• RRPIC understand Safeguards fundamentals • Obligations recognized under NPT and non-proliferation treaties, including SSAC establishment • Implementation and enforcement of safeguards legislation planned • Notification of intent to consider a research reactor sent to IAEA SG department	• Terms of international safeguards agreement with IAEA in place; • SSAC established and operational; • Safeguards-relevant information provided to IAEA; • Specific safeguards legislation and procedures are in place	• All safeguards measures and an effective SSAC are in place before initial fuel loading, including Design Information Verification by the IAEA Safeguards department; • Information regarding all relevant nuclear material subject to safeguards instruments provided to the IAEA.

Infrastructure issue	**Milestone 1 — Ready to make a knowledgeable commitment to a research reactor project**	**Milestone 2 — Ready to invite bids for the research reactor**	**Milestone 3 — Ready to commission and operate the research reactor and its ancillary facilities**
(8) Radiation protection	• RRPIC understands: o Specific radiation hazards of a research reactor and ancillary facilities; o The need to enhance national laws and expand safety infrastructures; o Need for radiation protection requirements and practices equivalent to those provided by the IAEA BSS and SS; o Need for training of radiation protection personnel for the regulatory body and the operating organization.	• Preparations and plans for radiation protection programmes in place; • Existing laws governing radiation protection reviewed and updated; • Specific radiation protection regulations developed; • Background radiation sources characterized and measured.	• Radiation monitoring and protection programmes in place to minimize radiation exposure to the public and workers; • Programmes to minimize radiation exposure during research reactor operation, maintenance and utilization have been established; • Associated training programmes completed.
(9) Utilization	• RRPIC confirms rationale for the reactor and its ancillary facilities: • Pre-Project Assessment submitted to RRPIC; • Major stakeholders identified and consulted; • Range of potential utilization of the research reactor studied; • Mechanisms identified to ensure continued stakeholder input on research reactor utilization; • Regional and international cooperation considered; • Sustainable utilization is specifically addressed in the Strategic Plan for the research reactor.	• Utilization requirements for the research reactor project addressed; • Required ancillary facilities studied, including any facilities needed for: o Utilization; o Shipping of product; o Staff training.	• Operating organization has: • Developed detailed operational plans for each of the areas identified in the Utilization Plan; • Developed a marketing plan; • Updated the Strategic Plan.
(10) Human resources development	• Knowledge and skills needed to support a research reactor project identified by RRPIC; • A plan exists to develop and maintain the human resources.	• Sufficient human resources are in place to write technical specifications, issue the bid request, evaluate bids and perform site selection and characterisation • Initial education and training for remaining human resources for plant operation identified and financial resources committed	• Human resources to commission and operate the research reactor and its facilities are in place • Education and training programmes to ensure continuing availability of qualified people are underway
(11) Stakeholder involvement	• Stakeholders have been systematically identified and consulted; • There is interaction and communication with the stakeholders and general public regarding the research reactor project; • Public information programme initiated by the AMPT and RRPIC.	• Public information programme developed by all involved organizations.	• Credibility with stakeholders and public established; • Socio-political involvement maintained; • Stakeholder consultations have continued through construction and preparation for operation.
(12) Site survey, site selection and evaluation	• General assessment and survey of potential sites completed primarily using existing data; • Potential sites ranked in order of merit.	• Initial site characterization performed; • Suitable site(s) for bid selected.	• All site services and provisions in place and functional; • All site security must be in place; • All site environmental monitoring underway.

Infrastructure issue	**Milestone 1 — Ready to make a knowledgeable commitment to a research reactor project**	**Milestone 2 — Ready to invite bids for the research reactor**	**Milestone 3 — Ready to commission and operate the research reactor and its ancillary facilities**
(13) Environmental protection	• RRPIC has assessed: o Any unique environmental issues; o The need to enhance existing environmental laws and regulations.	• Environmental studies for selected sites performed; • Particular environmental sensitivities included in bid specifications; • Initial environmental impacts and improvements assessed; • Responsibilities of the regulatory body and other environmental agencies clearly defined.	• Programmes for monitoring and assessment fully implemented in compliance with international standards; • Specific environmental requirements identified and included in the operating licence conditions; • The site and its surroundings characterized to define the baseline condition; • Provisions for the storage, transport and disposal of waste in place.
(14) Emergency preparedness and response	• RRPIC understands: o The need for emergency planning; o The need for communications between the operating organization and local and national government; • RRPIC has identified national institutions that could support emergency preparedness.	• Emergency planning issues have been taken into account during the site selection process; • Options for sheltering and public evacuation considered according to the potential hazard of the planned research reactor, and any impediments identified; • Agreements for local and national authority participation identified and preliminary discussions held.	• Emergency plans completed, tested, reviewed and approved by the regulatory body; • Written procedures in place between the operating organization, local and national authorities and regulator; • Emergency notification systems are in place and thoroughly tested; • Impediments to protective actions (for example sheltering, evacuation, and medical responses) have been removed; • Emergency drills and exercises have been run.
(15) Security and physical protection	• RRPIC understands the IAEA security fundamentals, and requirements for security and physical protection; • Nuclear Security legislation identified; • RRPIC recognizes need for: o Operating organization to have prime responsibility for security; o An effective legal framework for security, including an independent regulatory body; o Effective leadership and management for security; o Arrangements to prevent and mitigate malicious acts.	• Nuclear Security legislation enacted; • Security requirements defined and security issues included in the bid specification; • Threats for diversion of radioactive materials have been evaluated; • Sensitive information is defined; • Local and national law enforcement assistance established; • Programmes for selection/qualification of staff accessing to facilities or sensitive information are in place.	• Operating organization, regulatory body and related organizations have effective security cultures; • Regulatory body has: • Authority to assess security culture and to take appropriate action; • Reviewed the security plan and change control system; • Operating organization: • Understands the design of the nuclear security system; • Has contingency plans and protocols established with response organizations and has conducted joint exercises; • Physical protection is provided by trained security staff.
(16) Nuclear fuel management	• RRPIC understands: o Nuclear fuel cycle issues and alternatives; o Need for spent fuel storage, processing or disposal, including associated policies and financing.	• Fuel cycle strategy developed, including fresh fuel supplies and spent fuel management.	• Research reactor fuel supply contractually committed; • On-site spent fuel storage available for at least a full core of fuel.
(17) Radioactive waste	• RRPIC has reviewed the current policies and capabilities for waste disposal; • RRPIC recognises the additional responsibilities for radioactive waste from the research reactor, including: o The need for a radioactive waste management policy; o The options and costs for long term management and disposal of radioactive waste; o Recognized the value of becoming a Contracting Party in the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive waste Management.	• Strategy for waste management and disposal developed • Responsible organization and funding system for waste management and decommissioning established	• Plan for disposal of all waste categories developed; • Facilities for the processing and storage of low and intermediate level radioactive waste fully operational; • Regulator confirmation that plans for radioactive waste management and decommissioning comply with regulations.

Infrastructure issue	**Milestone 1 — Ready to make a knowledgeable commitment to a research reactor project**	**Milestone 2 — Ready to invite bids for the research reactor**	**Milestone 3 — Ready to commission and operate the research reactor and its ancillary facilities**
(18) Industrial involvement	• National policy with respect to domestic industrial involvement considered; • Recognized the need for strict application of quality programmes for nuclear equipment and services.	• Domestic industrial capabilities and motivation assessed, as well as the investments needed to enhance capabilities if needed.	• Sources of national supply to support operation of the research reactor and its facilities assessed; • Supplier qualification requirements established.
(19) Procurement	• AMPT and RRPIC recognize: • Project management requirements associated with purchasing a research reactor and ancillary facilities; • Need to validate the proposed design on safety and technical grounds; • Need for consistent procurement and industrial involvement policies.	• Procurement programme consistent with national policy for industrial participation established; • Operating organization able to carry out nuclear procurement, including project management and design review; • Preferred nuclear technologies determined; • Bid evaluation criteria determined; • Contracting strategy established.	• Operating organization procurement organization established.

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ABBREVIATIONS

AMPT	assessment, marketing and project team
AP	Additional Protocol
BNCT	boron neutron capture therapy
BSS	basic safety standard
CSA	Comprehensive safeguards agreement
DBT	design basis threat
HEU	high enriched uranium
INSAG	International Nuclear Safety Group
IP	intellectual property
LEU	low enriched uranium
OBT	operator building team
RRPIC	Nuclear Research reactor project Implementing Team

NPT	Treaty on the Non-Proliferation of Nuclear Weapons
RR	research reactor
RRPIC	Research Reactor Project Implementing Agency
SAR	safety analysis report
SQP	small quantities protocol
SSAC	State System of Accounting for and Control of Nuclear Material
SWOT	strengths, weaknesses, opportunities and threats analysis
TC	technical cooperation
UNSCEAR	United Nations Scientific Committee on Effects of Atomic Radiation

Annex I.

RESEARCH REACTOR OVERVIEW

Research reactors are research and technology infrastructures allowing the acquisition of knowledge, expertise and awareness, and provision of services in several fields such as nuclear power sciences, education, fundamental matter studies, medical applications and other services including industry.

They have provided essential support for these objectives over the last 60 years and a large number of research reactors have been implemented (see Fig. I–1).

Because they meet different needs, these research reactors present quite different design features.

Research reactors are generally cooled by water at low temperature (room temperature or slightly above) and low pressure (one to a few bars). This provides the necessary flexibility required to implement the required research capacity and services to industry.

It is worth pointing out the difference between water cooled research reactors and the so-called experimental reactors that are prototypes for power reactors with coolant such as sodium (BOR-60 in the Russian Federation), gas or lead-bismuth. After some period for testing technologies, these experimental reactors may offer services complementary to research reactors but not with the same flexibility and economy. Experimental reactors can be found in countries promoting new power reactor technologies, such as fast neutron reactors.

For the purpose of simplicity, one can group research reactors into a few technical families characterised by a consistent set of technical specifications and applications.

Of course, a more in-depth survey would take into account complementary criteria such as the power density, which impacts the neutron flux level, the associated experimental equipment, and supporting or attached facilities and infrastructure, and other criteria.

For simplicity, we will consider three main types of research reactor, according to their level of thermal power:

- From 0 to a few kW, corresponding to zero power research reactors;
- From a few hundred kW to 10 MW, corresponding to multipurpose reactors;
- Above 10 MW, corresponding to high performance research reactors for fundamental research applications or for advanced support to the nuclear industry.

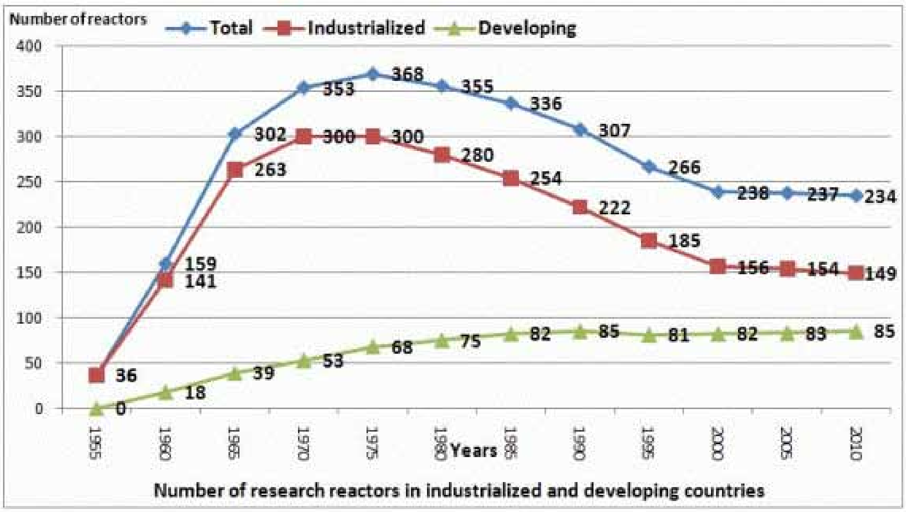

FIG. I–1. Worldwide research reactors in operation versus time. Source: IAEA RRDB (2009).

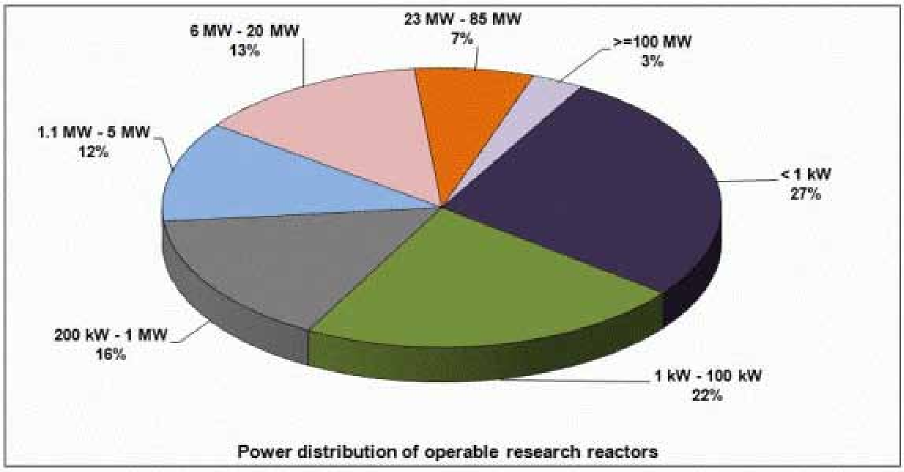

FIG. I–2. Distribution of worldwide research reactors in operation according their power. Source: IAEA RRDB (2009).

I–1. ZERO POWER REACTORS

I–1.1. Purpose

Experimental programmes in zero power reactors (ZPR) address neutron physics, a central discipline for fission reactors. Experiments are designed to yield information on basic nuclear data such as nuclei cross sections and to validate computer simulation codes in configurations representative of power reactors. For that purpose, and owing to the small power, the core configuration can be easily modified by rearranging fuel elements and absorbing materials.

ZPRs provide support for teaching and training of the teams operating reactors, and a focus for the development of a nuclear safety culture.

I–1.2. Brief description

ZPRs are rather simple installations, principally constituted of:

— Fuel elements presenting great flexibility of assembly, placed in a metal tank inserted into a concrete block;
— Biological protections to limit exposure to radiation in the reactor building, when this is in operation;
— A water circuit for filling the reactor tank; this is a simple circuit without cooling function.

A ZPR can be operated by 3 or 4 people. Maintenance and operations/controls can require 5 or 6 more people. Because there is no fuel consumption and minimal waste production, the operation cost for ZPR is small.

I–1.3. Risks related to ZPRs

ZPRs present a small risk level of, because of the very low level of power:

— There is no risk related to the cooling of fuel elements;
— There is no need to renew the fuel (no consumption, no cladding ageing) and therefore no transport issue;
— Dynamic confinement in the reactor building is enough due to the very low quantities of radioactive products present in the fuel elements.

Principal risks are related to handling and criticality management. Risk mitigation is obtained by operator training, limiting the handling of heavy loads, and limiting the fuel quantities to be handled simultaneously.

I–2. MULTIPURPOSE REACTORS (A FEW kW < POWER < 10 MW)

I–2.1. Purpose

Multipurpose research reactors enable a large spectrum of activities such as:

- Education and training;
- Analysis by neutron activation;
- Production of common radio-isotopes (iodine, rhenium, samarium, molybdenum, etc.);
- Study of the matter by using neutron beams (diffraction, diffusion, etc.);
- Tests small components behaviour under irradiation: materials, detectors, sensors, etc.;
- Neutron radiography and tomography;
- Neutron transmutation: doping of silicon and gemstone coloration.

The production of radio-isotopes is an important activity for research reactors; one may propose a rough segregation of the production capacity versus the research reactor power as shown in Table 10.

Operating a multipurpose reactor will require competences for maintenance, radiological surveillance, management of waste and effluents, safety, security. For that reason, multipurpose reactors offer an effective platform for teaching, for training and for preparing future power reactor operators.

It is not possible to make a general statement on the operation economy of a multipurpose reactor. Fuel consumption and related cost may vary by an order of magnitude depending on the operation/utilisation. In the same time, the revenues from industry will depend on the available competences, on the effectiveness of the commercial and technical organization, on complementary investments such as experimental devices, on transport capacities for nuclear material. In the field of services supply, there is a strong competition between research reactors and it is difficult to obtain significant revenues from services to industry.

I–2.2. Brief description

Multipurpose reactors are of the open-core swimming pool type. The facilities are principally constituted of:

- Core maintaining structures, placed in a pool inserted into a concrete block;
- Cooling water circuits for the core and the pool and the associated secondary circuits;
- Cooling systems for the water of the secondary circuits;
- In-core and out-of-core experimental devices;
- Confinement systems;
- Facilities in the reactor building to exploit experiments (shielded cell, glove box, underwater workstation, etc.);
- Storage areas in the reactor building for fresh fuel and for irradiated fuel elements;
- Resources in the reactor building or close to it for treatment and storage of radioactive waste and effluents.

TABLE 10. RADIOISOTOPE PRODUCTION CAPABILITIES OF RESEARCH REACTORS

Research reactor power ~a few MW	Research reactor power ~7 ≤ Power ≤ ~15 MW	Research REACTOR power ~40 ≤ Power ≤ ~100 MW
131I, 51Cr, 60Co, 82Br, 153Sm, 192Ir, 203Hg, 99Mo, 32P, 35S, 166Ho, 133Xe	131I, 51Cr, 60Co, 82Br, 153Sm, 192Ir, 203Hg, 99Mo, 32P, 35S, 166Ho, 133Xe	131I, 51Cr, 60Co, 82Br, 153Sm, 192Ir, 203Hg, 99Mo, 32P, 35S, 166Ho, 133Xe
	90Y, 24Na, 41Ar, 192Yb, 177Lu, 125I, 252Cf, 194Sb, 59Fe	90Y, 24Na, 41Ar, 192Yb, 177Lu, 125I, 252Cf, 194Sb, 59Fe
		7Li, 79Kr, 89Sr, 182Ta, 186Re, 188Re, 203Hg, 197Hg, 14C, 169Yb, 33P, 32P, 140La, 169Er, 46Sc, 51Cr, 72Ga, 137Cs, 42K, 51Mn, 64Cu

The reactor can be operated by a team of five people; for day time operation (respectively continuous operation), 2 teams (respectively 4 teams) are necessary. Maintenance operations and controls require additional 10 to 20 people according to the size of the facility.

Experimental activities require supplementary staff.

I–2.3. Risks related to multipurpose reactors

Cooling of the core fuel elements is a major safety function. For limited power (2 MW or less), this can be performed by natural convection within the pool water. For higher power, forced water circulation in a primary circuit is necessary. In all situations, it is mandatory to keep the core immersed.

Controlling reactivity insertion is another major safety function and is obtained from the primary design of the core (maximum insertable reactivity, favourable effects of counter-reactivity), engineered safety features and from the operation performance (training and awareness of operators, procedures usage, etc.).

Dynamic confinement in the reactor building is sufficient, considering the low quantities of radioactive products present in the fuel elements and the role of retention of the pool water in the event of cladding failure of the fuel elements. Contamination from radioisotopes production activities is also considered.

Depending on the effective operated power, the fuel consumption may range from occasional fuel renewal (once every 10 years) to annual fuel renewal. This requires mastering fuel handling and transportation.

I–3. HIGH-PERFORMANCE RESEARCH RECTORS (POWER ≥10 MW)

I–3.1. Purpose

The use of these high-performance research reactors includes:

- **Radioisotope production.** Large scale production of radioisotopes for industrial and medical uses is a major use of these reactors. Most of the worldwide supply of Mo-99 (the source for Tc-99m used for medical imaging) is obtained by irradiating and then processing enriched uranium targets;
- **Fundamental research applications.** Large reactors provide high quality neutron beams that are able to characterise the properties of the matter by using neutron scattering techniques (examples include HFR at ILL in France; Budapest Research Reactor in Hungary; FRM-II in Germany; OPAL in Australia; HANARO in the Republic of Korea);
- **Materials studies.** For example, magnetism studies, material basic science, investigation of soft matter (polymers, large molecules, solvents, etc.), understanding of living processes for biology, chemistry, research on disordered systems (liquids, glasses);
- **Studies of materials and fuels behaviour under irradiation.** These studies typically support nuclear energy development and safety (for example the Halden reactor project, Norway). These research reactors, so called material testing reactors, offer high thermal and fast neutron flux to test material and fuel in conditions relevant for power reactors. Applications include lifetime management and extension for existing and future nuclear power reactors, fuel performance improvement and behaviour validation in transient and accidental situations, innovative fuel and material development for future power reactors.

I–3.2. Brief description

High performance reactors are pool type reactors, with powers ranging from 10 MW(th) to 100 MW(th) and in a few cases even higher. To reach high performance, complex technologies and sophisticated computation tools are involved in the reactor design and within the reactor operation.

The safe operation of these reactors requires redundant systems, advanced control system and skilled staff. These reactors are operated continuously with an experienced staff (50 or more people). The large fuel consumption to provide this performance requires effective management of the whole fuel cycle, including a robust back end solution.

The level of the available neutron flux makes possible the production of proliferating materials and requires special arrangements for the reactor operations and material control.

The operation costs of high performance reactors are important (from few million Euros per years up to few tens of millions of Euros per year). In the same time, these reactors provide revenues from services delivered to the industry (utilities, nuclear vendors, medical industry, silicon industry, etc.). Nevertheless, it should be emphasised that in general public subsidies equivalent to a significant fraction of the operation costs are required to balance yearly expenditures and with the available revenues.

I–3.3. Risks related to high performance reactors

High performances result from optimized designs and margins, coupled with sophisticated operations. To guarantee safe operation high technical skills and an appropriate environment are needed.

These reactors are in general open to international collaboration which offers good opportunities to train technical and scientific staff from collaborating countries.

I–4. RESEARCH REACTOR TYPE VERSUS APPLICATION AND CONTEXT

Zero power reactors only require limited means for their set up and operation. But they are rather specialized facilities providing experimental capacities in neutronics and reactor physics for the benefit of countries deeply engaged in nuclear science.

The multipurpose reactors with MW class power offer the opportunity to buildup relevant competences for a subsequent NPP programme. The investment costs vary depending on the technical environment and can range from a few million euro (for the reactor internals when the infrastructures are available) up to several tens of millions of euro (when the reactors and complementary facilities have to be considered). These reactors present a good compromise for countries embarking upon a path toward nuclear energy because:

— They offer a large capacity for research and services;
— They require significant administrative and technical support with similarities to the requirements for power reactors.

High performance research reactors require costly infrastructure (several hundreds of millions of euro) and can be implemented most easily in countries with:

— Existing nuclear power plants in which the research reactor can be used to support present and future generation NPPs (lifetime management, material and fuel developments, fuel tests beyond the limits, operation optimisation, etc.);
— Available experience to operate high power research reactor in order to supply effective services (fundamental research on matter, radioisotopes production, etc.).

Annex II

ALTERNATIVE TECHNOLOGIES

Where a Member State decides to acquire or is seriously considering the acquisition of a multipurpose research reactor consideration of alternative technologies for some of those purposes may be warranted.

A simple low power (less than 1 MW) device can provide the means for the basic nuclear training of personnel in preparation for the acquisition of a nuclear power reactor. However if a larger multipurpose reactor (10–20 MW) is constructed then other uses become possible with measurable financial and capability benefits (see Annex I).

When the Australian Government decided to consider the purchase of a multipurpose reactor to replace the ageing HIFAR reactor, some groups opposed to the proposal argued that alternative technologies for the major uses were more attractive and would avoid the fission product release risk necessarily associated with the operation of a nuclear reactor. Both the spallation neutron sources and the cyclotron were considered as alternatives to the proposed reactor.

II–1. SPALLATION NEUTRON SOURCES

A spallation neutron sources comprise typically a source of high energy protons produced either by a cyclotron, a synchrotron or a linear accelerator. These protons are directed onto a heavy metal primary target resulting in a flux of high energy neutrons. Subsequently the neutrons are slowed to useful energies and are directed onto a secondary target of the material being studied. Spallation neutron sources are primarily designed and used for scientific research purposes and can operate both in continuous and pulsed modes. In particular, they can produce very high neutron fluxes in very short bursts with characteristics that are suitable for certain types of research, namely they can achieve very high outputs for research based on pulsed neutron beams (see Fig. 1).

There are five major spallation neutron sources operating in the world (LANCE, USA; SINQ, Switzerland; ISIS, UK; SNS, USA; J-PARC, Japan) with ESS, EU in the planning stage. However, none of them operate yet at a power range that would enable isotope production performance (using neutrons) equivalent to a 20 MW multipurpose research reactor. Indeed, spallation neutron sources are normally not designed for continuous operation and have not been used for the routine production of radioisotopes. Furthermore, there are no known proposals to use spallation sources for this purpose.

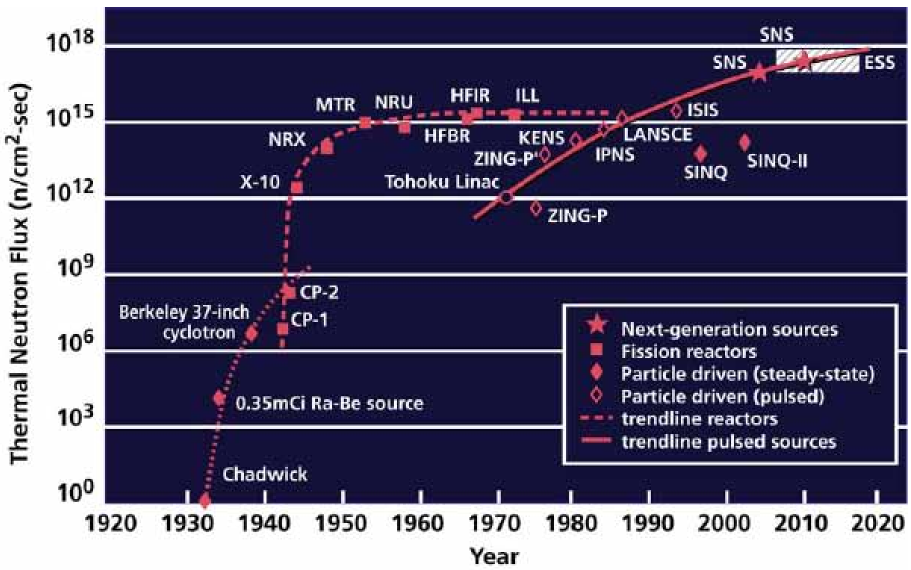

FIG. II–1. Available or projected thermal neutron flux with research reactors and spallation neutron sources.

When compared to a research reactor, the capital and operating costs of a spallation neutron source are significantly higher. With the exception of the AUSTRON proposal in Austria, all new spallation source proposals have capital cost estimates in excess of US$ 1 billion.

Consequently the acquisition of a spallation source as an alternative to upgrading the purchase of a low power training research reactor to a multipurpose research reactor is not recommended.

II–2. CYCLOTRONS

Whilst the fundamental difference between a cyclotron and a research reactor is clearly understood within the scientific world there is sometimes an understandable level of confusion between them in the minds of the general public.

Essentially a cyclotron generates positive particles-ions (protons, deuterons, alphas, etc.) that interact with target materials to produce neutron deficient radioisotopes. In contrast a research reactor produces neutrons and produces neutron rich radioisotopes as a consequence of neutron fission or neutron capture process. Therefore the two technologies are complimentary rather than competitive alternatives.

The major radioisotopes producing countries operate both a research reactor and one or more cyclotrons to produce the range of radioisotopes and radiopharmaceuticals required by nuclear medicine centres for the diagnosis and treatment of patients (for example, South Africa).

Annex III

NATIONAL VERSUS REGIONAL APPROACH FOR A RESEARCH REACTOR

III–1. NATIONAL RESEARCH REACTORS

Countries contemplating a research reactor are recommended to include regional research reactor facilities in their considerations. Most research reactors have been constructed as national facilities, with the user base, justification and funding defined in national terms. However, a research reactor that is designed to serve a regional user base may have access to more users, more funding, and additional opportunities for participation in the international scientific milieu. In total, these asepects may help to secure a fully utilized future for the research reactor.

An associated concept that should also be considered is whether joining a regional research reactor project as a user may be more cost-effective and provide greater opportunities than a national facility.

Table III-1 summarizes aspects of the national and regional research reactors.

III–2. CHECKLIST APPROACH FOR A REGIONAL CENTRE

If a decision is taken to proceed with a regional research reactor facility, the research reactor justification should be developed as discussed in Section 3, but with an expanded focus to cover the regional users and stakeholders. To achieve this effectively, enlist the help of regional partner organizations that can help to identify and survey their national stakeholders and build the justification for the research reactor.

III–2.1. Establishment of a Memorandum of Understanding (MOU) between countries/organizations

The implementation of the regional research reactor centre should start with an MOU that covers the following:

- Operational management structure;
- Waste management;
- Construction, commissioning, operation and decommissioning costs;
- Distribution of revenue;
- Sharing of facilities/capabilities;
- Fuel fabrication and supply;
- Regulation (legal basis, costs, independence);
- Environmental impact assessment.

TABLE III-1. ADVANTAGES AND DISADVANTAGES OF NATIONAL AND REGIONAL RESEARCH REACTORS

National research reactor	Regional research reactor
Advantages	
• Unilateral science and technology knowledge infrastructure; • Industrial climate easily overseen; • Funding simpler to organize, but from a smaller financial base; • Short management lines; • Long term support of only one government needed.	• Possibility to create a more capable, better equipped reactor with broader utilisation capability; • Regional centre for human resource/skill development; • Cost sharing reduces individual costs to participating nations and organizations.
Disadvantages	
• Smaller stakeholder and customer base; • Governmental policy changes can more significantly impact budgets and staffing; • Changes in national economic and industrial situation have stronger influence on budget arrangements; • Human talent pool is smaller than with regional resources.	• Disputes between nations sharing reactor financially and organizationally; • Siting deliberations are more complex; • More time is required to agree on specifications, siting, construction, and operation details; • Agreement on cost sharing may be difficult; • Waste repository sharing regulations may be time consuming.

Decisions as to the primary uses of the reactor should be made at an early stage, for example, whether the research reactor is to be used as a training aid in preparation for a nuclear energy support programme, or for scientific research, or both. At least one year should be allowed to achieve a consensus on this decision.

With the MOU in place and a justification that shows that the research reactor is necessary, the implementation should proceed with the remaining phases and milestones in the infrastructure development programme.

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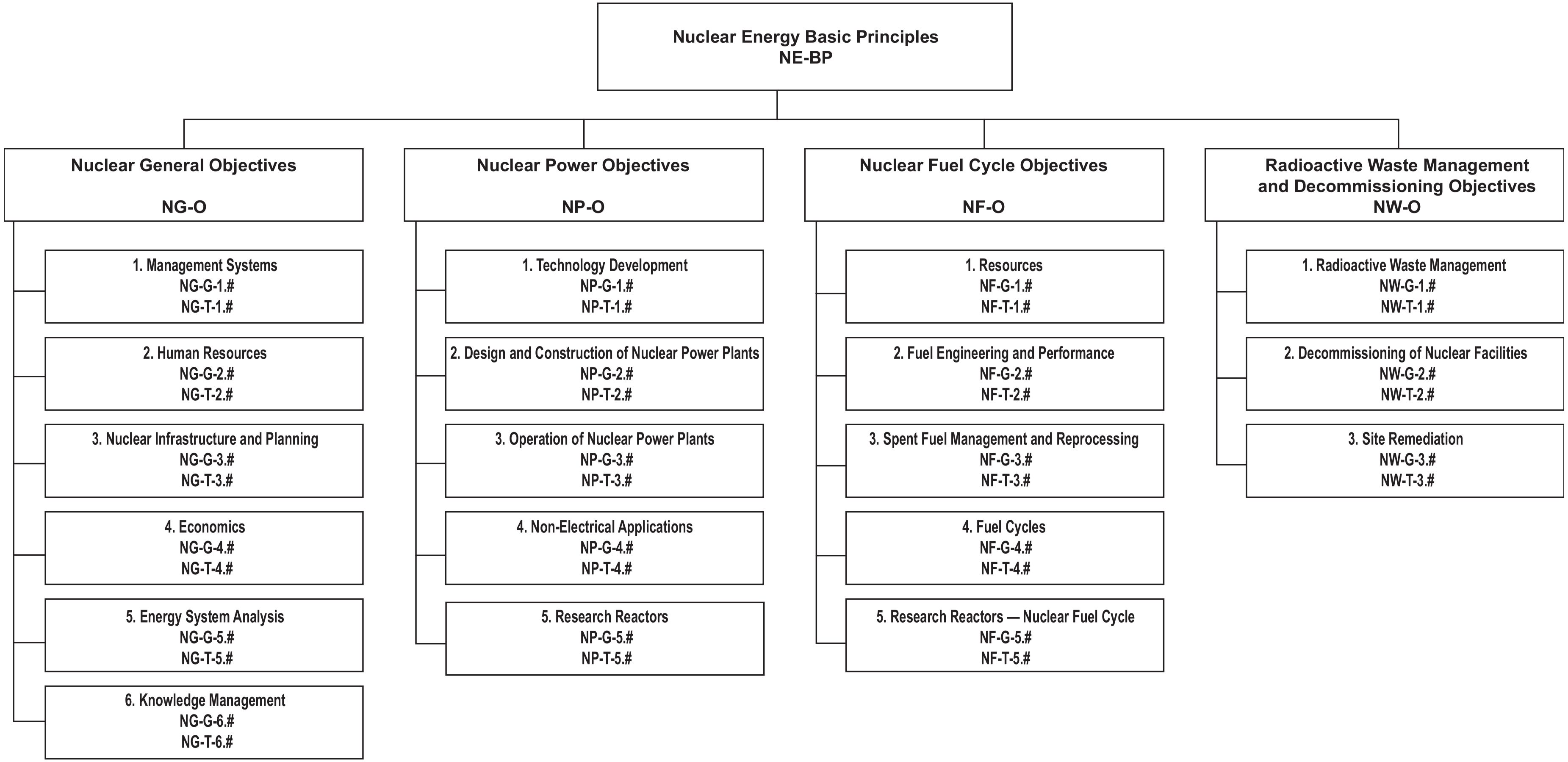

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ISBN 978–92–0–127610–0
ISSN 1995–7807