IAEA GUIDELINES FOR NEW RESEARCH REACTOR PROJECTS

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ABSTRACT

In recent years, the interest of the IAEA Member States in developing research reactor (RR) programmes has been steadily growing. Currently a number of Member States are in different stages of new research reactor projects. Some of these Member States are building their first research reactor as their country's introduction to nuclear science and technology infrastructure.

To support Member States in such efforts, the IAEA published in 2012 a Nuclear Energy Series Report NP-T-5.1: "*Specific Considerations and Milestones for a New Research Reactor Project*". This publication provides guidance on the timely preparation of a research reactor project through a 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 of the project. The publication provides a discussion of the mechanisms for justification of a research reactor, and for building stakeholder support. It includes both the technical, legal, regulatory and safety infrastructure, and the development of qualified human resources needed for a research reactor. The publication also addresses 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, start-up, and preparation for commissioning. The subsequent stages of operation, decommissioning, spent fuel and waste management issues are addressed in the publication to the degree necessary for appropriate planning prior to research reactor commissioning.

The feedback from the IAEA activities, in particular from Member States establishing their first research reactor, indicated the need for further guidance on the development of the technical specifications for the bidding process of a research reactor project. In responding to these needs, a Nuclear Energy Series Report on "*Technical Requirements in the Bidding Process for a New Research Reactor*" (Nuclear Energy Series Report NP-T-5.6) was developed and is currently under publication process. This document is meant to bridge the gap between the feasibility study for a new research reactor and the call for bids. The publication also addresses the preparation phase of the bidding process and discusses criteria that may be used in the evaluation of the bids. The guidance applies to all reactor types and technologies and it is not recommending a specific reactor type or technology or a specific design. However, it is assumed that the publication will be used by a Member State that has made a knowledgeable commitment to build a safe, sustainable, robust-design and easy-maintainable research reactor. While the guidance provided by this publication is intended

mainly to be used by Member States building their first research reactor, it might be suitable for Member States building a subsequent one.
The above mentioned publications should be used in conjunction with the IAEA publications on research reactor safety and utilization, in particular the Code of Conduct on the Safety of Research Reactors and the supporting IAEA Safety Standards.
This paper presents an overview of the publications and discusses follow-up activities with Member States for their effective application.

1. INTRODUCTION

Many Member States (MSs) have informed the IAEA of their interest in constructing a research reactor (RR), as their first major nuclear investment and opportunity to benefit from the peaceful uses of nuclear technology. These future RRs may have various roles, such as: a) promoting science, technology and medical purposes; b) providing services for society; c) serving as a major facility for nuclear education and training, and d) contributing to build expertise to support a nuclear power programme. In responding to this trend, the IAEA published last year a comprehensive report on "*Specific Considerations and Milestones for a New Research Reactor Project*" [1]. The document emphasizes that some fundamental circumstances must be considered before embarking on a new project, such as: a) the RR project will create long term obligations for the safe operation of the reactor and proper management of the associated spent fuel and radioactive waste; b) These new projects are set in a context where currently almost half of the world's existing RRs are underutilized, facing budgetary and human resources resource challenges, that may affect their operational condition. Moreover, the publication provides guidance on the timely preparation of a RR project through a sequential development process (*Phases*), and includes a detailed description of the range of infrastructure issues that need to be addressed and the expected level of achievement (*Milestones*), at the end of each phase of the project. Furthermore, the publication provides a discussion of the mechanisms for building stakeholder support to justify a new RR, and addresses the evolution of infrastructure needs from the time a MS first considers a RR and its associated facilities, through the stages of planning, bid preparation, construction and preparation for commissioning. It includes technical, legal, regulatory and safety infrastructure, and emphasizes the development of qualified human resources needed for a RR.
The feedback from the IAEA activities, in particular from MS establishing their first RR, indicated the need for further guidance on the development of the technical specifications for the bidding process of a RR project. In responding to this need, the IAEA has recently finalized the development of a Nuclear Energy Series Report on "*Technical Requirements in the Bidding Process for a New Research Reactor*" [2]. The scope of this publication covers the bidding process, from the preparation of the technical part of the Bid Invitation Specifications (BIS) until the selection of the RR design and the signature of the contract, including criteria for bid evaluation. It indicates that all these processes are to be used in conjunction with the other IAEA publications on RR safety and utilization and the supporting IAEA Safety Standards. As so, the new document is to be used to bridge the gap between the feasibility studies (Milestone 1) and bid specification (Milestone 2), as depicted Fig. 1. The guidance applies to all reactor types and technologies, and as so is not recommending a specific reactor type or technology or a specific design. However, it is assumed that the recent document will be used by a MS that has already decided that general features as: *safe, sustainable, robust-design and easy-maintainable RR* is appropriate to be considered the country's needs, as it establishes its first nuclear installation. Moreover, the guidance provided in the publication is primarily oriented to countries developing its first RR; however, such guidance could be also used for the bidding process of a subsequent reactor in a country. Furthermore, the publication is mainly directed to the turnkey contractual approach, but it is also useful in other kinds of contractual approaches.

This paper presents a brief overview of the leading IAEA published publication [1], listing the conditions to reach each Milestone, along with an overview of the main technical contents of the recent IAEA publication [2], and discusses the activities in supporting its MS for its effective application.

2. SPECIFIC CONSIDERATIONS AND MILESTONES FOR A NEW RESEARCH REACTOR PROJECT [1]

STRUCTURE OF THE PUBLICATION

The IAEA publication on "*Specific Considerations and Milestones for a New Research Reactor Project*" [1] is structured of seven chapters. Session 1 provides the background, the objectives and defines the use of the publication. Session 2 presents the infrastructure development phases, namely the Pre-Project, Project Formulation and Project Implementation phases, considering the subjects to be addressed during these phases. Session 3 is referring to the important phase of RR's justification; moreover, the chapter elaborates the process of identifying the stakeholders needs with emphasize on securing the long term government commitments associated with operation of a RR and considering regional and international cooperation while preparing the strategic plan. The next three Session, 4 to 6, are describing in details the three Milestones that indicate the completion of each phase, to be followed during a RR project: a) Ready to make a knowledgeable commitment; b) Ready to invite bids; c) Ready to Commission and operate the RR and its auxiliary facilities. Finally, in Chapter 7, the authors conclude the various chapters of the publication and summarize recommendations. For further details and understanding of the document, it is recommended to download the document from the IAEA Web-site (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1549_web.pdf).

MILESTONE 1: *READY TO MAKE A KNOWLEDGEABLE COMITTMENT*

In order to reach the first Milestone, the key issues which require completion include: a) statement of commitment to ensuring safety, security and non-proliferation of nuclear material through to the relevant international legal instruments; b) identification of any intergovernmental agreements required to support technological support and/or fuel cycle services; c) participation in the Global Nuclear Safety Regime, and promoting leadership and management for safety, including the building of a strong safety culture; d) implementation of a legal framework covering all aspects of nuclear law, which includes safety, security, safeguards, nuclear liability and other legislative, regulatory and commercial aspects; e) establishing an effective independent, regulatory body responsible for safety and security; f) availability of adequate human resources to operate, maintain and regulate the RR and its ancillary facilities; g) allocating funding, programmes and resources for the decommissioning processes, and the safe, secure management of spent fuel and radioactive waste.

MILESTONE 2*: READY TO INVITE BIDS FOR THE RR*

In order to reach the second Milestone, the State must carry out the work required to prepare for the construction of a RR. Therefore, the following activities have to be completed: a) the nuclear legislation will need to be enacted before proceeding with a request for bid for the first RR; b) the regulatory body will need to be developed to a level at which it can fulfill all of its oversight duties and prior 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; c) the necessary infrastructure should be developed to the point of readiness to request a bid or enter into a commercial contract; d) an effective management system and staff capabilities to ensure proper accomplishment of the operating organization (OO) obligations; e) the OO 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; f) the potential users of the RR and customers of its products and services should be consulted during the drafting of the technical specifications for

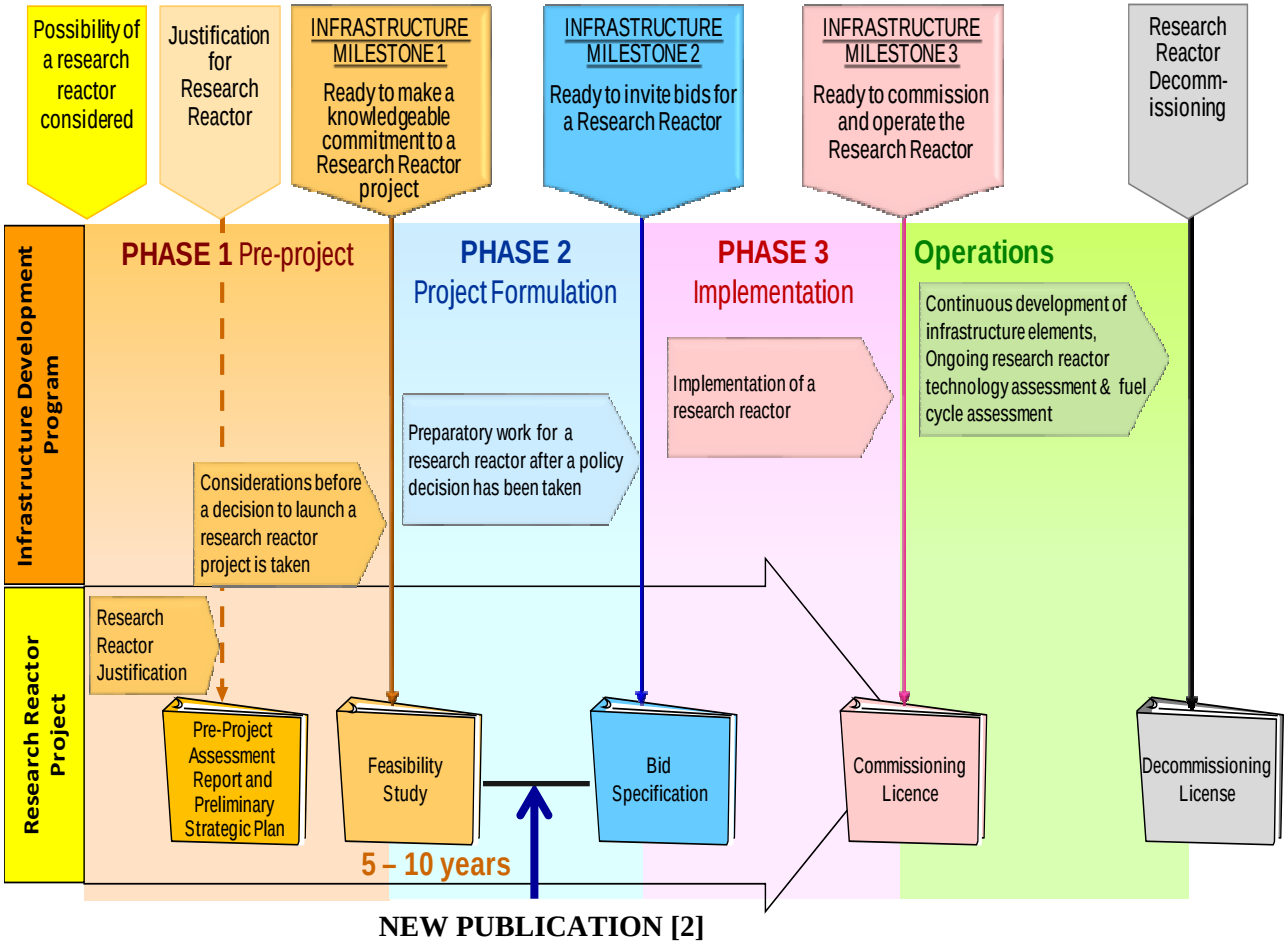
the reactor and its ancillary facilities, as user community endorsement of the project specification is a condition of Milestone 2; g) a detailed site characterization should be completed for one or more sites that meet the national criteria for nuclear facility application; h) the environmental characteristics of the potential sites for the RR and its ancillary facilities should be known and the specific challenges for environmental monitoring at the chosen site identified; i) though not all implementation of Emergency Plans details need to be in place to achieve Milestone 2, it should consider both the RR facilities and the surrounding community; j) an effective national legislative and regulatory framework to regulate nuclear security has been established, including a threat evaluation for radioactive material and the RR, which the regulatory body should use as a common basis for determining nuclear security requirements and inclusion of security considerations in the bid specification; k) the OO should develop a fuel management strategy as an input for the bid invitation and include the arrangements for obtaining replacement fuel, if needed, the management and disposition of spent fuel and establish an operational radioactive waste management programme for the RRs.

MILESTONE 3*: READY TO COMMISSION AND OPERATE THE RR AND ITS ANCILLARY FACILITIES*

In order to reach the third Milestone, the completion of all the activities necessary to commission and operate the first RR and the related infrastructure development, must be achieved. The OO will have developed from an organization capable of ordering a RR to an organization that can accept responsibility for commissioning and operating one. Moreover, the procedures and arrangements to ensure safe control of RR 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 RR. To attain Milestone 3, the OO should: a) 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; b) ensure that financing is sufficient to sustain the safe operation of the RR and its facilities, and financing mechanisms have been established for the eventual decommissioning of the RR and related; c) complete an adequate safety review and assessment of the facility design and implementation and prepare with the supplier and provide for the RR the Safety Analysis Report (SAR), commissioning programme, operating programme, controls and emergency plans to the regulatory authority.

The regulatory authority should complete preparing all regulations, codes and standards for construction of a RR and its ancillary facilities were put in place, with sufficient staffing for the effective review and licensing of nuclear facilities. Prior to nuclear fuel loading, the regulatory body should issue the licenses required for commissioning of a RR. 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. Moreover, regulatory inspections are expected to begin during the site preparation and construction stages in Phase 3, and will become eventually more intensive during the commissioning and operation stages. These inspections should aim at verifying that the RR and associated activities comply with the latest approved safety (SAR, Operational Limits and Conditions, emergency plan, radiation protection programme, etc.), safeguards, and security documentation. Furthermore, in order to reach the Milestone 3, the regulatory body must confirm that the licensee has demonstrated compliance with the relevant regulatory requirements.

FIG 1: Research Reactor project and infrastructure development programme [1]. The arrow indicates the place of the new IAEA publication [2] within the project.



3. THE DOCUMENT ON DEVELOPING BID INVITATION SPECIFICATIONS [2]

The scope of the recent IAEA publication *Technical Requirements in the Bidding Process for a New Research Reactor* [2] is to cover the bidding process for a new RR, from the preparation of the technical requirements of the Bid Invitation Specifications (BIS) until the selection of the RR design and the signature of the contract, including criteria for bid evaluation. The publication is to be used in conjunction with the other IAEA publications on RR safety and utilization and the supporting IAEA Safety Standards. As so, the new document is to be used to bridge the gap between the feasibility studies (Milestone 1) and bid specification (Milestone 2), as depicted Fig. 1.

STRUCTURE OF THE DOCUMENT

The publication is structured as follows: Section 1 provides description of the background, objectives and scope of the publication. Section 2 discusses the general considerations of the bidding process, including description of the bidding process and its preconditions, the entities involved in the bidding process and their responsibilities, as well as other important aspects such as schedule of the bidding process and pre-qualifications of the bidders. Section 3 provides description of the general considerations for developing the BIS, including among others the site selection and specification process, the general design requirements, the main issues regarding the fuel supply and the bid evaluation criteria. These items are presented along with discussions on the relevant information that

should be included in the technical specifications of the BIS. Section 4 addresses reactor utilization related design features. A list of the various applications of research reactors is presented along with the technical requirements that can shape the owner/operator's (Member State's) request from the vendor during the bidding process. Section 5 provides description of the fundamental design requirements for the research reactor that should be included in the technical specifications of the bid. Special emphasis is given to the IAEA safety requirements and to the requirements for safety demonstration to be included in the BIS. Section 6 provides guidance on the reactor organizational structure during operation phases together with the training requirements as well as the items to be requested from the vendor in this regard. Section 7 presents guidance on the technical documents to be requested from the reactor vendor as well as the technical documents that should be prepared by the operating organization but inputs may be requested from the vendor in the frame of the bidding process. Section 8 provides a list of infrastructure related facilities (including software) that have to be specified by the operator and supplied by the vendor to build, operate and safely utilize the new research reactors facility. Section 9 discusses the bid evaluation process and provides guidance on performing such an evaluation from technical and economical point of view. Suggested set of bid technical evaluation criteria is also discussed.

CONCEPTUAL SAFETY ASSESSMENT

The main deliverable related to safety during the design phase will be the Preliminary Safety Analysis Report (PSAR) prepared by the vendor based on the safety oriented description and safety assessment of the facility [3].The PSAR is not part of the bid. Nevertheless, at the bid stage, a conceptual safety assessment should be prepared by the vendor to demonstrate compliance with safety acceptance criteria and objectives. The generic process for the safety analysis is described in IAEA publications [3], [4]. The main approach for the safety demonstration has to follow deterministic methods, though probabilistic methods can be used as complementary tool. For deterministic methods, the approach defining accidental sequences and emergency planning must be defined. For probabilistic methods, the risk integrates the likelihood and the severity of each of the consequences. A safety assessment is an integral component of the design process and has to be carried out following standard practices [4]. It provides a feedback mechanism to the designers for verification that the proposed design solutions comply with safety acceptance criteria. Therefore, some preliminary assessment of the safety of the facility must be part of the documentation required from the vendor during the bidding process. The process of safety assessment is presented in the Fig. 2 as a summary diagram.

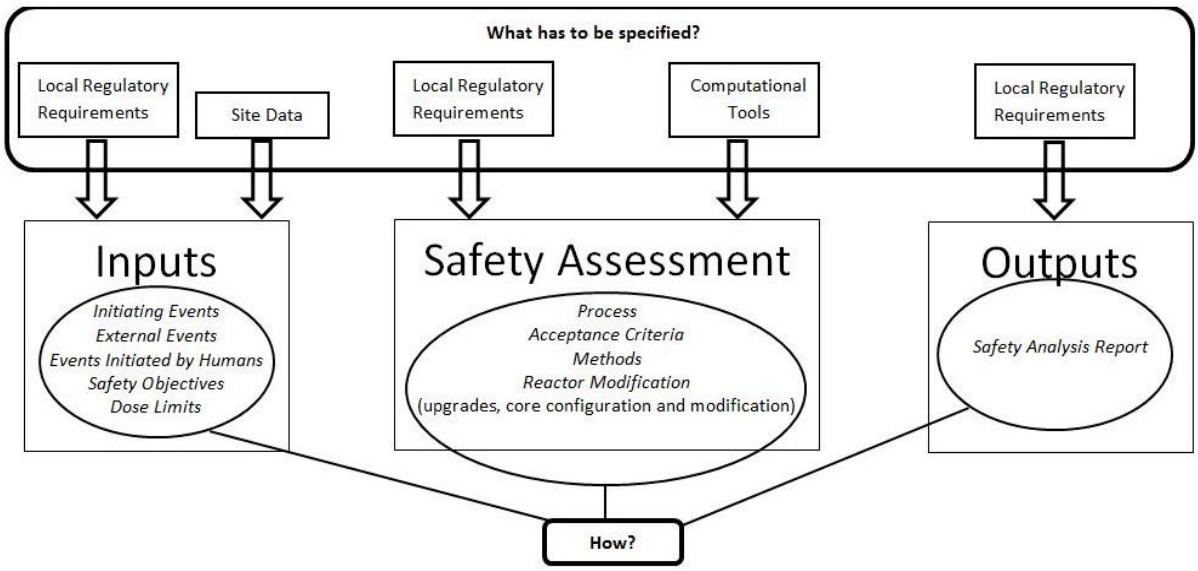
FLEXIBILITY IN OPERATION AND MAINTENANCE

The "easy care" distinctive features of the design refer mainly to the followings (additional detailed requirements are provided in IAEA Safety Standards [5] and [6]) and include, among others:

- User (operator/experimentalists)-friendly, flexible and easy to maintain;
- Provision of extended period between physical inspections or maintenance of reactor systems;
- Reduction of the need for local human actions through the use of automated systems;
- Refuelling the core is not frequently required and can be easily carried out;
- Radiation levels during operation are minimised, and the radiation level in the reactor hall is low enough to allow workers and users to access the hall during reactor operation;
- Human machine interface is based on proven, state-of-the-art technology and demonstrated to be user-friendly;
- Design features to ease maintenance are included, such as provision to store coolant during pool maintenance activities.

The design should provide easy access to the reactor core and to the experiments. The demands on the operator should be minimized by the design so as to reduce the burden on the operator and bound human error by adopting clear displays, audible signals and automated safety actions.

FIG. 2: Diagram of the proposed conceptual Safety Assessment process [2].



HUMAN RESOURCES

During the pre-project phase [1] (see Fig. 1) it is strongly recommended to develop the following human resources: a) technical expertise to develop specifications for the RR and to evaluate the bids taking into account constructability and commissioning, operability and maintainability, safety and licensing, utilization, fuel cycle, radioactive waste management and decommissioning, safeguards, security and emergency planning; b) project management expertise to manage the bidding process, to develop specifications and to evaluate the bids; c) existing knowledge of the country's and of the site's infrastructure (such as geological survey capability, services infrastructure, etc.) as well as the international best practices including IAEA Safety Standards and the regulatory requirements, often necessary to be established or upgraded and expedited during the bidding process; d) legal and financial expertise for BIS preparation, bid evaluation, contract negotiations and fuel procurement and e) expertise in communication and public information.

REQUIREMENTS FOR THE VENDOR

The following topics have to be provided by the vendor: a) information on the implementation of measures of defence in depth [7], in order to identify and implement prevention and mitigation measures for all postulated initiating events in the design of the facility. The mitigation measures must be actuated by engineered safety features or on-site procedures established by the operator; b) a description of the methodology used for the safety classification of Systems Structure and Components (SSCs). This information has to include: the number and description of safety categories or classes adopted and the requirements on the design, quality assurance (QA), time of performance, time between maintenance requirements for SSCs in each safety category; c) a preliminary list of acceptance criteria for all SSCs performing a safety function, such as actuation time, acceptable delays and negativity reactivity worth inserted by shutdown system, and the means used to demonstrate that the acceptance criteria are met by the design, in each operational and accident state; d) a list of all the codes and standards that will be used in the design and construction of the reactor. This list must contain mandatory national standards and international standards, including IAEA Safety Standards. This list must remain contingent to the acceptance of the OO and the regulatory authority. In the absence of such codes and standards, the results of experience, tests,

analyses or a combination of these may be applied, and this results based approach have to be justified; e) all necessary information on the computational tools that are used in the safety analyses of the facility; f) information on previous experience with the code and all the work that has been done previously to demonstrate that the software is applicable to calculate the conditions of the reactor; g) information for the applicability of all correlations, equations, approximations and models to the range of conditions analysed with the software, including all information pertinent to the verification of the code.

BID EVALUATION CRITERIA

The bidding process is divided in several main phases: i) preparation of the BIS (by the (OO); ii) preparation of bids (by bidders); iii) evaluation of bids (by the OO); iv) contract negotiations (by the OO and selected bidders); v) signature of the contract (by the OO and contractor). The evaluation criteria may include the following items: a) compliance of the bid with the contents and requirements of the BIS; b) experience, reputation, organization, facilities, services and financial resources of the bidder; c) project structure, project organization and implementation plan of the bidder; d) safety features of the design; e) compliance of the bid with the IAEA Safety Standards; f) technical characteristics of the RR, status and provenness of design, standardization, constructability; g) operability, useability, inspectabilty and maintainability of the facility; h) project schedule; i) quality management practices, procedures and measures; j) assurance of fuel supply and fuel cycle services; k) assurance of nuclear safety, demonstrated licenseability of the facility, environmental effects, waste management; l) Type and contents of documentation provided; m) flexibility of the operation and ease of maintenance; n) national participation (local contractors and suppliers) and technology transfer, training programme; o) quality and extent of follow-up services of the bidder during the facility operation; p) price adjustments, currency requirements, terms of payment and warranties;

4. CONCLUSIONS

The paper reviews two IAEA recent publications: the first aims to provide guidance on the timely preparation of a research reactor project through a sequential development process that includes a detailed description of the range of infrastructure issues that need to be addressed and the expected level of achievement at the end of each phase of the project; the second addresses the preparation phase of the bidding process and discusses criteria that may be used in the evaluation of the bids. The guidance provided applies to all reactor types and technologies, so this publication therefore is not recommending a specific reactor type or technology or a specific design. The documents are mainly directed to the turnkey contractual approach, but they may also be useful in other kinds of contractual frameworks.

Construction and operation of a RR 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 RR 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 RR. If the RR 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 RR itself. Three well defined 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 RR project will be safe, secured, cost effective and able to achieve its full potential.

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