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# INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Infrastructure

INPRO Manual

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# INPRO METHODOLOGY FOR SUSTAINABILITY ASSESSMENT OF NUCLEAR ENERGY SYSTEMS: INFRASTRUCTURE

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INPRO MANUAL

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# FOREWORD

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

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

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

The International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) was launched in 2000, based on resolutions of the IAEA General Conference (GC(44)/RES/21). One of the INPRO objectives is to help to ensure that in the twenty-first century nuclear energy is available in a sustainable manner. To meet this objective, INPRO has proceeded in steps. In its first step, referred as Phase 1, INPRO developed a set of basic principles, user requirements and criteria, together with an assessment method, which, taken together, constitute the INPRO methodology for the evaluation of a national or global nuclear energy system with regard to its long term sustainability. The methodology was documented in the form of an assessment manual and comprised an overview volume and eight other volumes covering the areas of economics, infrastructure, waste management, proliferation resistance, nuclear security, environment, safety of reactors and safety of nuclear fuel cycle facilities. The first edition of this manual was the IAEA TECDOC 1575 Rev.1, published in 2008.

In its second step, referred to as Phase 2, Member States participating in INPRO are performing national and international nuclear energy system assessments (NESAs) using the INPRO methodology. The results of the nuclear energy system assessments conducted up to 2009 were documented in IAEA-TECDOC-1636, published at the end of 2009, which includes several proposals on how to update the INPRO methodology based on the experience of the assessors. In parallel, the INPRO steering committee, IAEA experts and the INPRO group have also developed some recommendations on how to update the methodology.

All the proposals and recommendations were evaluated by internal and external experts at an IAEA Consultants Meeting in 2012. Based on the outcome of these consultancies, the INPRO manual was updated. This publication covers the area of infrastructure of the INPRO methodology.

The IAEA officers responsible for this publication were A. Korinny and J. Phillips of the Division of Nuclear Power.

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# SUMMARY

This publication is an update of Volume 3 of IAEA-TECDOC-575/Rev.1 (2008), Guidance for the Application of an Assessment Methodology for Innovative Nuclear Energy Systems, in the area of infrastructure, based on recommendations presented by Member States participating in the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), IAEA experts and the IAEA/INPRO group.

This publication provides guidance on assessing a nuclear energy system (NES) in the area of nuclear infrastructure. Within the INPRO methodology, a nuclear infrastructure can be defined as the collection of necessary capabilities of national institutions to achieve long term sustainability of a nuclear power programme. The INPRO methodology defines a series of measures to be taken by these national institutions such as: the establishment of a legal framework, i.e. the nuclear law and the corresponding nuclear regulatory bodies, the selection of an appropriate site for nuclear facilities by their future owner/operator and the building up of a national industry in support of the owner/operator. Two specific aspects are discussed in more detail in this publication, namely the importance of public acceptance of a nuclear power programme and the necessary human resources to establish and operate such a programme. Additionally, the INPRO methodology defines measures that a designer and the State should take to reduce the necessary effort to establish and maintain a nuclear infrastructure.

In the INPRO methodology area of infrastructure, there is one basic principle, six user requirements and several criteria for each user requirement.

Experience has shown that establishing and maintaining an adequate nuclear infrastructure requires a significant investment of time and effort — especially for the first nuclear power plant to be installed in a country — and thus may be a potential barrier for starting a nuclear power programme. These considerations are reflected in the basic principle of the INPRO methodology in this area by setting the goal that the establishment of an adequate infrastructure shall not require an excessive investment by a country that intends to start, maintain or expand a nuclear power programme.

The first four user requirements in the INPRO methodology in the area of infrastructure are to assure a national nuclear infrastructure that is adequate for a long term sustainable NES by covering the issues of a legal nuclear framework (user requirement UR1), the role of national industry (user requirement UR2), public acceptance of nuclear power (user requirement UR3) and human resources (user requirement UR4) in a nuclear power programme. The user requirement UR5 asks the developer to minimize the necessary nuclear infrastructure by design and the user requirement UR6 asks the country to use regional and international arrangements to reduce the effort to establish and maintain a nuclear infrastructure.

The establishment of a nuclear power programme entails legal commitments at both the national and international levels. These commitments give rise to the need to establish a legal framework that provides the basis for establishing a national nuclear safety and liability, nuclear security, non-proliferation, radiation protection and environmental protection regime to control and oversee the installation, operation and decommissioning of nuclear facilities. This need is expressed in the user requirement UR1. A legal framework comprises two aspects, legal requirements set out in nuclear related legislation, referred to as nuclear law and including related regulations and guides, and the related institutional infrastructure including regulatory authorities that must give effect to the nuclear law and ensure that the legal commitments are met. The most important international legal commitments for a country with a nuclear power programme are treaties, such as the Treaty on the Non-Proliferation of Nuclear Weapons, and the related Safeguards Agreements and Protocols, and conventions, such as the Convention on Nuclear Safety. To cover the first aspect of a nuclear legal framework, the INPRO assessor is asked to check whether the (existing or planned) nuclear law covers all areas important for a nuclear power programme, the law is formulated in accordance with international standards, important international nuclear legal arrangements are in place and whether the regulation and guidelines are complete and adequate. To cover the second aspect of a nuclear legal framework, the INPRO assessor is asked to check whether competent state organizations for regulating a nuclear power programme have been established (or are planned).

The user requirement UR2 requires that an adequate industrial and governmental support infrastructure is available in a country with a nuclear power programme to support the owner/operator of nuclear facilities during construction, maintenance and repair during operation, and decommissioning. The INPRO assessor is asked to check whether the necessary financing is available to upgrade the national industry in accordance with the planned participation in the nuclear power programme and whether the necessary government funds are available for

establishing the support infrastructure within the responsibility of the State, such as adequate roads and bridges for transport of bulky nuclear components. Further, the assessor should confirm that the size, location and role (e.g. providing baseload) of a planned nuclear power plant fits the national electricity grid.

The user requirement UR3 emphasizes the need to achieve and maintain public acceptance of nuclear power in a country with a nuclear power programme. Public acceptance of nuclear power is to be achieved by informing the public continuously about all nuclear issues, by enabling public participation in the decision process regarding a nuclear power programme and by building public trust in nuclear regulatory bodies and operators of nuclear facilities. The INPRO assessor is asked to check whether sufficient and adequate information about a nuclear power programme being planned or in operation is provided to the public by the State, regulatory bodies and the operators of nuclear facilities; whether the public have been enabled to participate adequately in the decision process related to a nuclear power programme; and whether sufficient public acceptance of a nuclear power programme has been achieved based on public polls performed on a regular basis.

The user requirement UR4 deals with the necessary human resources for a successful nuclear power programme. Skilled and trained personnel are needed for successfully implementing, maintaining or enlarging such a programme, primarily by the operator of nuclear facilities, but by also all other institutions involved in a nuclear power programme such as nuclear regulatory bodies and the nuclear industry. The INPRO assessor should check whether an effective education system is in place or being developed to train the human resources needed for a nuclear power programme. Such a system should offer qualifications at all three levels of training: skilled trades, technicians, and professional engineers and scientists in nuclear science and technology. The assessor should further check whether the national nuclear power sector is attractive enough to ensure that trained and experienced personnel can be kept within the nuclear power programme rather than moving to more attractive jobs in other areas.

The user requirement UR5 asks the designer of a nuclear facility to reduce the necessary nuclear infrastructure by design measures. This corresponds to the goal of the basic principle to avoid an excessive investment in a nuclear infrastructure. The following aspects of a nuclear infrastructure could be influenced by the design of a facility: the amount of personnel needed to operate and perform maintenance and repair in a nuclear facility and the extent to which prefabrication of components can be utilized to reduce construction works. The INPRO assessor is asked to check whether a new design of a nuclear facility shows superiority in the above presented aspects in comparison to an existing facility[1].

The user requirement UR6 asks governmental institutions and the owner/operator of nuclear facilities in a country to check regional and international arrangements that could reduce the effort to build and maintain a national nuclear infrastructure. Examples of such available arrangements are the World Nuclear University established with the support of the IAEA, contracts of the build–own–operate (BOO) type offered by some suppliers of nuclear technology and the harmonization of licensing between the technology supplier and user country.

Thus, for an NES to be sustainable in the long term, it requires the development and maintenance of an adequate legal framework, an industrial capacity to support the nuclear power programme during its lifetime, a sufficient level of public support combined with a commitment by the government, and the necessary human resources to assure safe and secure operation of its nuclear energy system. To minimize the effort needed to create a nuclear infrastructure, the designer is asked to optimize the design by, for example, reducing the necessary human resources to operate nuclear facilities, and the country is asked to use all available international and regional arrangements.

The manual can be used to look at infrastructure requirements in a country considering whether to acquire its first NPP, when planning for an expansion of an existing nuclear power programme and/or for a replacement of currently operating plants when they reach the end of their useful life, or when planning the installation of other components of an NES or, for example, when manufacturing fuel.

The manual is not intended to provide specific guidance on creating a necessary infrastructure, but focuses on assessing the status of an infrastructure, whether already existing or being planned, with regard to its long term sustainability. For a country embarking on a nuclear power programme, specific guidance on creating an adequate infrastructure to operate the first nuclear power plant is provided in the IAEA publication Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy Series No. NG-G-3.1, and by the related IAEA peer review service Integrated Nuclear Infrastructure Review offered to Member States.

[1] 'Existing facility' is defined in updated publications on the INPRO methodology as a facility of the latest design operating in 2013.

# 1. INTRODUCTION

This publication is an update of the guidance given in the area of infrastructure in Volume 3 of IAEA-TECDOC-1575 Rev.1 (2008), Guidance for the Application of an Assessment Methodology for Innovative Nuclear Energy Systems [1]. It is based on recommendations presented by Member States participating in INPRO, IAEA experts and the IAEA INPRO group.

The information presented in the overview manual of the updated INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems[2] should be considered to be an integral part of this publication and the user should be familiar with that information.

## 1.1. BACKGROUND

Applying the INPRO methodology in an assessment is a bottom up exercise and consists of determining the value of each of the INPRO methodology indicators (of a criterion) and comparing the value with the corresponding acceptance limit for the given criterion. Based on the comparison, a judgement on the capability of a nuclear energy system (NES) to comply with the criterion is made.

The ultimate goal of the application of the INPRO methodology is to confirm that the NES assessed fulfils all the criteria, and hence the user requirements and basic principles, and therefore represents a long term sustainable system for a Member State (or group of Member States). Basic principles, user requirements and criteria have been defined in different areas — economics, infrastructure, waste management, proliferation resistance, environmental impact of stressors, environmental impact of depletion of resources, and risk reduction by design in nuclear reactors and fuel cycle facilities (nuclear safety).

One possible output from an assessment is the identification of areas where a given NES needs to be improved to achieve long term sustainability. Given the comprehensive nature of an assessment using the INPRO methodology, such an assessment would be expected to indicate clearly the specific attributes of an NES that need to be improved, and so could be an important input to identifying necessary or desirable research, development and demonstration objectives.

An example of a detailed national infrastructure assessment using the INPRO methodology in a country embarking on a nuclear power programme is available in Ref. [2]. A comprehensive INPRO assessment of the nuclear infrastructure needed for an innovative NES consisting of fast reactors with a closed fuel cycle is documented in Ref. [3].

## 1.2. SCOPE

Issues other than technical requirements for NES are important to potential users of nuclear energy. Many of the factors that will either facilitate or obstruct the ongoing deployment of nuclear power over the next fifty years and beyond relate to infrastructure — national, regional and international.

Within the INPRO methodology, the term infrastructure can be defined as a collection of necessary capabilities of national institutions to achieve the long term sustainability of a nuclear power programme in a given country. These capabilities are essential for successful deployment and operation (or expansion) of an NES, and require legal (e.g. nuclear law) and institutional (e.g. regulatory bodies), industrial and economic (e.g. support to the owner/operator of a nuclear power plant) and sociopolitical measures (e.g. public acceptance and human resources).

The definition of an NES includes, in addition to the reactor, all nuclear fuel cycle facilities (i.e. components) at both the front end of the fuel cycle (e.g. mining/milling, conversion, enrichment, fuel fabrication) and the back end (e.g. reprocessing, storage and disposal of waste) and associated infrastructure. Consequently, infrastructure is a part of the NES to be assessed; however, within the INPRO methodology, a reactor and related nuclear fuel

[2] A publication on this subject is in preparation.

cycle facilities are not considered to be a part of a national infrastructure, albeit that they influence the size of the necessary infrastructure required in a given country, region and globally.

## 1.3. OBJECTIVE

It is generally recognized that to operate nuclear facilities, particularly a nuclear power plant (NPP), safely and securely, a sophisticated infrastructure is required. Countries that already operate NPPs will, in general, already have an appropriate infrastructure in place, but this is unlikely to be the case for a country that has not yet acquired its first NPP.

The manual can be used to look at infrastructure requirements in a country considering whether to acquire its first NPP, planning for the expansion of an existing nuclear power programme, and/or for replacing currently operating plants when they reach the end of their useful life, or when planning for other components of an NES, for example, for fuel manufacturing.

The manual is not intended to provide specific guidance on creating the necessary infrastructure, but focuses on assessing the status of the infrastructure, whether already existing or being planned. For a country embarking on a nuclear power programme, specific guidance on creating an adequate infrastructure is provided in the IAEA publications entitled Milestones in the Development of a National Infrastructure for Nuclear Power [4] and Evaluation of the Status of National Nuclear Infrastructure Development [5], and by the related IAEA peer review service Integrated Nuclear Infrastructure Review (INIR) [6] offered to Member States by the IAEA.

An assessment using the INPRO methodology should lead either to the confirmation that an established (or planned) infrastructure is adequate for the nuclear power programme planned (or in operation) or to the definition of actions that need to be taken to achieve an adequate infrastructure.

Planning for a first NPP, or for the enlargement of an existing NES, and planning for addressing the associated infrastructural issues are closely linked and one necessitates the other. On the other hand, establishing or upgrading the necessary infrastructure takes time and effort and so actions to this end are unlikely to be started until energy system planning has clearly identified nuclear power as an option for (additional) energy supply that should be seriously considered. Thus, in this publication, the discussion of infrastructure requirements also involves on occasion a discussion of energy system planning, since, at least at the early stages of planning, infrastructure planning and energy system planning are interwoven and interdependent activities. For example, energy system planning, when considered in isolation from infrastructure, may indicate that an NPP should enter into operation within a relatively short time frame. But ensuring the infrastructure (existing or planned) is adequate to acquire and safely operate especially the first NPP may require a significantly longer time. So, the energy system planning process cannot be completed without considering the related infrastructure planning process.

## 1.4. STRUCTURE

In Section 2, the main information that is needed for an INPRO assessment in the area of infrastructure is specified. In Section 3, background information concerning the basic principle of INPRO, user requirements and criteria in the INPRO methodology area of infrastructure is set out and a process for evaluating the criteria is presented. From the discussion in the preceding section, it is clear that a number of factors or topics need to be considered in the area of infrastructure. These factors are grouped together and discussed in Section 3 of the manual, under the following general headings, each of which represents a user requirement (UR) in the area of infrastructure:

— Legal and institutional considerations (UR1);
— Industrial and economic considerations (UR2);
— Political support and public acceptance (UR3);
— Human resources (UR4);
— Minimization of infrastructure (UR5);
— Regional and international arrangements (UR6).

The basic principle, user requirements and the corresponding criteria in the INPRO methodology area of infrastructure are set out in Table 1.

## 1.5. THE CONCEPT OF SUSTAINABLE DEVELOPMENT AND ITS RELATIONSHIP WITH THE AREA OF INFRASTRUCTURE OF THE INPRO METHODOLOGY

The United Nations World Commission on Environment and Development Report (often known as the Brundtland Report)[3], entitled Our Common Future, defines of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (para. 1). Moreover, this definition:

"contains within it two key concepts:

- the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."

This simple definition of sustainable development suggests a three part test for any approach to sustainability and sustainable development: (1) current development should be fit for the purpose of meeting current needs with minimized environmental impacts and acceptable economics; (2) current RD&D programmes should establish and maintain trends that lead to technological and institutional developments that serve as a platform for future generations to meet their needs; and (3) the approach to meeting current needs should not compromise the ability of future generations to meet their needs.

At first reading, this definition may appear obvious, but when considering the complexities of implemented nuclear energy technology and systems, plus their many supporting institutions, meeting the three part test is not always straightforward since many approaches only meet one or perhaps two parts of the test in a given area and may fail on the others.

The commission report's overview of the topic of nuclear energy summarized it in the following way:

> "After almost four decades of immense technological effort, nuclear energy has become widely used. During this period, however, the nature of its costs, risks, and benefits have become more evident and the subject of sharp controversy. Different countries world-wide take up different positions on the use of nuclear energy. The discussion in the Commission also reflected these different views and positions. Yet all agreed that the generation of nuclear power is only justifiable if there are solid solutions to the unsolved problems to which it gives rise. The highest priority should be accorded to research and development on environmentally sound and ecologically viable alternatives, as well as on means of increasing the safety of nuclear energy."

[3] UNITED NATIONS, Our Common Future (Report to the General Assembly), World Commission on Environment and Development, UN, New York (1987).

TABLE 1. OVERVIEW OF BASIC PRINCIPLE, USER REQUIREMENTS AND CRITERIA IN THE INPRO METHODOLOGY AREA OF INFRASTRUCTURE

Infrastructure basic principle: A country shall be able to adopt, maintain or enlarge an NES for the supply of energy and related products without making an excessive investment in national infrastructure[a].

| User requirements | Criteria | Indicator (IN) and acceptance limit (AL) |
|---|---|---|
| UR1: Legal and institutional infrastructure:<br><br>An adequate legal framework should be established to cover issues of nuclear liability, safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, security and non-proliferation[b] | CR1.1: Legal aspects | IN1.1: Status of legal framework<br><br>AL1.1: Legal framework has been established in accordance with international standards |
| | CR1.2: Institutions | IN1.2: Status of State organizations with responsibilities for safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, emergency preparedness and response, security and non-proliferation<br><br>AL1.2: State organizations have been established, in accordance with international standards |
| UR2: Industrial and economic infrastructure:<br><br>The industrial and economic infrastructure of a country with an NES[c] should be adequate to support the project throughout the complete lifetime of the nuclear power programme, including planning, construction, operation, decommissioning and related waste management activities | CR2.1: Funding of infrastructure | IN2.1: Funding needed for the infrastructure of a nuclear power programme<br><br>AL2.1: Sufficiently available to cover the nuclear power programme |
| | CR2.2: Size of nuclear facility | IN2.2: Size of nuclear installation<br><br>AL2.2: Matches local needs |
| | CR2.3: Siting[d] | IN2.3: Process of siting a nuclear facility<br><br>AL2.3: Siting process has taken safety, security and environmental requirements into account in accordance with international standards |
| | CR2.4: Support infrastructure | IN2.4: Availability of infr astructure to support owner/operator<br><br>AL2.4: Internally or externally available |
| | CR2.5: Added value | IN2.5: Added value of a nuclear power programme to society<br><br>AL2.5: Added value > infrastructure investment by government necessary to support nuclear power programme |
| UR3: Political support and public acceptance:<br><br>Adequate measures should be taken to achieve and maintain public[e] acceptance of an NES being planned or in operation to enable a government policy commitment to support the deployment and operation of the system | CR3.1: Public information | IN3.1: Information provided to public<br><br>AL3.1: Sufficient according to national requirements, taking into account international practice |
| | CR3.2: Public participation | IN3.2: Participation of public in decision making process on a nuclear power programme<br><br>AL3.2: Sufficient according to national requirements, taking into account international practice |
| | CR3.3: Survey of public acceptance | IN3.3: Public acceptance of nuclear power<br><br>AL3.3: Sufficient to expect that the political risk of policy support for nuclear power is acceptable |
| | CR3.4: Policy support | IN3.4:.Government policy regarding nuclear power<br><br>AL3.4: Policy is supportive of nuclear power |
| | CR3.5: Political environment and investor risk | IN3.5: Long term political commitment to a nuclear power programme<br><br>AL3.5: Commitment sufficient to enable a return of investment |

| User requirements | Criteria | Indicator (IN) and acceptance limit (AL) |
|---|---|---|
| UR4: Human resources[f]:<br><br>The necessary human resources should be available to enable all responsible parties involved in a nuclear power programme to achieve safe, secure and economical operation of the NES during its lifetime | CR4.1: Human resources | IN4.1: Availability of adequate human resources to establish and operate an NES<br><br>AL4.1: Sufficient according to international experience |
| UR5: Minimization of infrastructure[g]:<br><br>The NES should be designed to minimize the necessary infrastructure for a nuclear power programme | CR5.1: Personnel | IN5.1: Human resources needed for operation, maintenance and repair and decommissioning<br><br>AL5.1: Amount of human resources is reduced in comparison to an existing facility[h] |
| | CR5.2: Prefabrication of components | IN5.2: Extent of prefabrication of components<br><br>AL5.2: Extent is increased in comparison to an existing facility |
| UR6: Regional and international arrangements[i]:<br><br>Regional and international arrangements should provide options that enable a country with an NES to minimize the infrastructure for a nuclear power programme | CR6.1: Options to reduce institutional infrastructure | IN6.1: Have regional and/or international arrangements to reduce the institutional infrastructure been considered?<br><br>AL6.1: Yes |
| | CR6.2: Options to reduce industrial infrastructure | IN6.2: Have regional and/or international arrangements to reduce the industrial infrastructure been considered?<br><br>AL6.2: Yes |
| | CR6.3: Options to reduce social political infrastructure | IN6.3: Have regional and/or international arrangements to reduce the social political infrastructure been considered?<br><br>AL6.3: Yes |
| | CR6.4: Options to reduce human resources | IN6.4: Have regional and/or international arrangements to reduce human resources been considered?<br><br>AL6.4: Yes |

[a] In comparison to TECDOC-1575/Rev.1 [1], the text of the basic principle has been shortened by replacing “Regional and international arrangements shall provide options that enable any country that so wishes” by “Countries shall be able”.

[b] In comparison to TECDOC-1575/Rev.1 [1], in UR1 the words “Prior to deployment of an INS installation the” was replaced by “An adequate”.

[c] In comparison to TECDOC-1575/Rev.1 [1] the text in UR2 “planning to install an INS” was replaced by “with a nuclear energy system”.

[d] In comparison to ITECDOC-1575/Rev.1 [1] one criterion, CR2.2: Energy market, was deleted and one was added: CR2.3 on siting.

[e] ‘Public’ refers to all stakeholders in a nuclear power programme, i.e. society.

[f] In comparison to TECDOC-1575/Rev.1 [1], wording of UR4 was modified by replacing “INS installation” by “nuclear energy system” and deleting the second sentence. The criterion on safety culture was moved to the INPRO methodology area of safety.

[g] In comparison to TECDOC-1575/Rev.1 [1], this UR5 has been added.

[h] An ‘existing facility’ is defined in the updated INPRO methodology as ‘a facility of latest design operating 2013’.

[i] In comparison to TECDOC-1575/Rev.1 [1] this UR6 has been added.

The commission presented its comments on nuclear energy in chapter 7, section III. In the area of nuclear energy, the focus of sustainability and sustainable development is on solving certain well known problems (referred to here as ‘key issues’) of institutional and technological significance. Sustainable development implies progress and solutions in the key issue areas. Seven key issues are discussed (in this order):

(1) Proliferation risks;
(2) Economics;
(3) Health and environment risks;
(4) Nuclear accident risks;
(5) Radioactive waste disposal;
(6) Sufficiency of national and international institutions (with particular emphasis on intergenerational and transnational responsibilities);
(7) Public acceptability.

The INPRO methodology for the self-assessment of sustainability and sustainable development of a nuclear energy system is based on the broad philosophical outlines of the commission’s concept of sustainable development described above. Twenty-seven years separate the publication of this report from the publication of the commission report and 13 years separate it from the initial consultancies on the development of the INPRO methodology in 2001. In the interim, significant historical events have starkly highlighted certain key issues. However, the key issues for the sustainable development of nuclear energy systems have remained essentially unchanged over nearly three decades.

By far the most notable events in the period with direct bearing on nuclear energy sustainability were related to non-proliferation, nuclear security, cost escalation of new construction and, most notably, the accident at the Fukushima Daiichi Nuclear Power Plant in 2011. The Fukushima Daiichi accident further clarified that nuclear safety is an issue of paramount sustainability and that external hazards associated with a particular site could be responsible for a dramatic common cause failure involving multiple reactor units.

In each INPRO methodology manual, a key issue of nuclear energy system sustainable development is examined. The structure of the methodology is a hierarchy of INPRO basic principles (BP), user requirements (UR) and specific criteria (CR) measuring whether the UR has been achieved. Under each BP, the CR include measures that take into consideration the three part Brundtland sustainable development test.

This INPRO manual focusses on the key issues of legal and institutional infrastructure (including the relevant international treaties, agreements, arrangements, etc.), certain supporting economic and industrial infrastructure, and certain sociopolitical factors that directly contribute to successful nuclear energy system development. The World Commission on Environment and Development Report, in recognition of the unique complexities of nuclear energy systems and their regulation, clearly indicated that sustainable nuclear development depends on the proper functioning and evolution of nuclear governance and related infrastructure. Without proper infrastructure and governance, a programme will at best fail to be sustainable in a given country. At worst, unfortunate events might ensue. In the case of serious accidents or environmental damage, public confidence may erode, making nuclear energy less sustainable in a broader sense.[4]

In the area of nuclear infrastructure, evidence of the existence and function of key elements, consistent with international law, standards and good practices, is a sufficient measurement of sustainability. International law, standards and good practices in this area are long standing and evolutionary in nature, capturing lessons learned that are critical to the sustainable development of a nuclear energy system now and in the future.

This INPRO manual tests whether or not this governance infrastructure is in place, consistent with international law, standards and good practice. Moreover, it tests whether this infrastructure is capable of supporting nuclear energy system expansion without a burdensome growth in infrastructure — is the infrastructure optimized for the current nuclear energy system and is it structured to support and lead to sustainable nuclear energy growth? The INPRO methodology does this through assessment of documented evidence under each CR. In the area of infrastructure, the majority of CRs take the form of yes/no questions regarding the existence and function of particular features of the infrastructure. Tests of progress and fitness for purpose are limited in this context. In these cases, evidence that a CR is met may be provided either by proper referenced documentation or through successful

[4] For example, the reaction of Germany, Japan and other countries to the Fukushima Daiichi accident.

completion of an IAEA mission process that focusses on a given subject matter (e.g., nuclear law, nuclear safety and security regulation, safeguards, etc.).

## 1.6. INTERESTED PARTIES OR ENTITIES AND THEIR RESPONSIBILITIES

A number of entities in a country have responsibilities that need to be met when planning for the acquisition of a first or additional NPP and for evaluating, planning for, putting in place, maintaining or upgrading the national infrastructure. These entities include the State itself, the owner/operator of the NPP, industrial entities, educational entities and others.

Thus, for example, the State has a role in energy system planning, even in a laissez-faire (non-regulated) market based economy, and to deploy a first NPP in a country requires the State to enact legislation and to put in place one or more oversight mechanisms and organizations — a regulatory authority. An NPP must be operated by some entity, by definition the owner/operator, who assumes prime responsibility for the safe and secure operation and maintenance of the NPP. Usually, the owner/operator also acts as the customer for the NPP construction project and leads the acquisition process. The owner/operator needs to be involved in the planning and may, depending on circumstances, even have the lead role in planning for the NPP and in articulating the benefits of doing so.

National industrial entities have a stake in the availability of energy at competitive prices and so have a stake in energy system planning. Therefore, industrial representatives, including energy supply companies, would be expected to participate in energy system planning. In fact, in a laissez-faire economy, energy supply companies, including electrical utilities, may play a leading role in energy system planning. Selected industrial entities may also have an interest in or be asked to contribute to the construction, operations and maintenance of the NPP. For example, local construction companies would be expected to participate in construction activities, engineering companies may wish to provide engineering support services to either the construction project or to operations (including decommissioning) or to both, and other companies may wish to supply components and/or maintenance and repair services. Such companies have an interest in participating in planning for infrastructure improvements, e.g. to identify requirements for their participation in the nuclear power programme and means for meeting these requirements, and may contribute through training, partnering, etc. Industrial entities may also act as proponents for an NPP.

One of the requirements for the safe and secure operation of an NPP is a skilled and knowledgeable management team and workforce to operate the plant. A competent and knowledgeable regulator is also needed to provide independent oversight. Therefore, educational institutions have an interest in the planning for the deployment of an NPP. They may be expected to and/or may wish to provide training programmes and courses in nuclear engineering and sciences, in technical training, in trades, etc. To do so, they themselves may have to upgrade their own capabilities.

The owner/operator of the NPP will have the prime responsibility for the safe and secure operation of the plant. The owner/operator may build up a domestic operations team, possibly supplemented with experts from abroad, to manage and operate the NPP. Creating such competence may be a lengthy and costly process but, should there be an intention to build and operate a series of plants, this may be a preferred approach. On the other hand, the owner/operator might contract with a foreign supplier to supply the operating team, or the supplier of the NPP might also be contracted to operate the plant under a so-called build–own–operate (BOO) model or under a build–operate–transfer (BOT) model. To do so requires a willing supplier and this will necessitate suitable contractual arrangements to limit the risks faced by the supplier. Regardless of the option chosen, the end result needs to be the same, namely that the plant will be operated by a competent operating organization, reporting to an identified owner/operator who is responsible for safe and secure operation.

While it is recognized that different options may exist by which the INPRO methodology requirements in the area of infrastructure can be met, the requirements are discussed using a generic terminology to represent the different types of entities that have to take on institutional responsibilities to ensure the safe, secure and economic use of an NPP in a given country, namely the State, the regulator or regulatory authority, the owner/operator, industry, educators, the public, etc. These responsibilities are summarized briefly below.

The responsibilities of the State in a nuclear power programme regarding infrastructure include:

— Making a long term commitment to nuclear energy;
— Enacting legislation including bilateral and multilateral agreements and conventions;
— Creating the licensing and regulatory authority;
— Establishing policies governing the nuclear power programme, including policies related to waste management, domestic industrial participation and training;
— Planning of the national nuclear power programme jointly with the owner/operator of the nuclear facilities and national industry;
— Providing adequate roads, bridges and ports suitable for the transportation of nuclear specific parts with unusual weight and dimensions;[5]
— Providing financial support and/or guarantees consistent with the energy, industrial and training policies.

The responsibilities of the owner/operator of a nuclear facility in a nuclear power programme include:

— Planning and development of the nuclear power project together with the relevant government agencies;
— Securing project financing;[6]
— Managing the acquisition of the facility, including preparing the request for bid, bid evaluation, project management[7], securing the necessary licenses and approvals, etc.;
— Operating the facility, including ensuring the availability of a competent and trained management and workforce to do so.

The responsibilities of the regulator in a nuclear power programme include:

— Establishing regulatory standards, codes and criteria, and guidelines for the design, construction, operation and decommissioning of nuclear facilities, including the safe and secure management of radioactive wastes generated;
— Reviewing and evaluating licensing documents, such as nuclear security and contingency plans, safety analysis and environmental reports of nuclear facilities;
— Authorizing construction, operation and decommissioning of a nuclear facility and the conduct of activities by a licensee, by e.g. issuing licenses, registration;
— Performing inspections, reviews, audits and enforcement activities to ensure compliance with established rules and regulations;
— Providing information about safety aspects of facilities and activities to the public, the media and interested parties.

It is to be mentioned that the State, the regulator and the operator have the responsibility to achieve public acceptance of the nuclear power programme.

## 1.7. HOW TO START A NUCLEAR ENERGY SYSTEM ASSESSMENT

If a country is considering its first NPP, it is recommended that, before undertaking an assessment in the INPRO methodology area of infrastructure, the INPRO assessor becomes familiar, in a general way, with the overall issues that need to be considered when undertaking a nuclear power programme. A detailed introduction to the topic is given in IAEA publications [7–10].

Following a graded approach, this publication can also serve as an introduction to this subject and as a guide to relevant literature that the assessor may wish to consult. Thus, this publication can be read simply to obtain some general guidance. In this case, the details of indicators and acceptance limits will be of less importance.

[5] These activities are sometimes provided by the supplier of the NPP depending on the contract.
[6] Financing could be supported by the government.
[7] Participation in project management depends on the type of contract.

However, actually performing an INPRO assessment requires an understanding of the INPRO methodology and the basic principle as described in this publication, user requirements and criteria in the area of infrastructure. So, before performing an assessment in the area of infrastructure the assessor needs to carefully review the overview publication of the INPRO manual[8] and the material presented in this manual. The assessor will also need to consult, periodically, the references cited in the manual.

# 2. NECESSARY INPUT FOR AN ASSESSMENT IN THE AREA OF INFRASTRUCTURE

This section first discusses the importance of performing energy system planning to define the role of nuclear power in an energy mix to satisfy the predicted growth of energy demand in a country. Subsequently, the main information needed for an assessment using the INPRO methodology in the area of infrastructure and its potential source is defined.

## 2.1. ENERGY SYSTEM PLANNING AND PLANNING FOR A NUCLEAR POWER PROGRAMME

Energy system planning is highly important for the success of a nuclear power programme, especially if it is the first nuclear project in a country, e.g. the installation of the first NPP. Energy system planning is discussed in Section 2 of the economics manual [11] of the INPRO methodology.

Energy system planning should:

- Define a technically feasible and economically optimized plan for the expansion of the energy supply;
- Examine the role of nuclear power in the energy supply plan of the country.

However, energy system planning does not form a part of an assessment using the INPRO methodology per se. In general, the INPRO methodology assumes that an NES has been specified to contribute to meeting a defined (future) energy demand. The INPRO methodology is then used to determine whether the INPRO methodology requirements are met, in which case the NES represents a sustainable source of energy.

In case of an intended installation of a (first or additional) NPP, the final outcome of the energy system planning phase should be the specification of the contribution, as a function of time, that nuclear technology will make to the energy supply in a country (or region, or globally). The specified role for nuclear power should be technically and economically feasible. Thus, the results of an energy system planning study should be available to the INPRO assessor.

Countries can obtain assistance for their energy system planning from the IAEA.

## 2.2. NECESSARY INFORMATION TO PERFORM AN ASSESSMENT IN THE INPRO METHODOLOGY AREA OF INFRASTRUCTURE

In this section, for each user requirement, UR1 to UR6, the main input data needed for an assessment and their potential source are discussed.

In the NES assessment (NESA) support package (see Section 4.3 of the overview publication of the INPRO manual[9]), examples of input data available on the internet for an INPRO assessment are provided.

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[8] A publication on this subject is in preparation.

[9] A publication on this subject is in preparation.

### 2.2.1. Legal and institutional infrastructure (UR1)

The INPRO assessor needs to have access to information on national legal and institutional measures, such as the legal framework (in place or planned) related to nuclear power, and on the capabilities of regulatory and other organizations with responsibilities for nuclear safety, radiation protection, environmental protection, emergency preparedness and response, non-proliferation and nuclear security.

The source of this information should be the responsible national government organizations such as the regulatory bodies, the ministry of energy and the ministry of the environment. If the country has recently used a relevant IAEA service that reviews, on the request of Member States, national legal and institutional infrastructure, the INPRO assessor should use the results of these IAEA services as a source of input. Examples of relevant IAEA services are: the Integrated Regulatory Review Service (IRRS), the Emergency Preparedness Review Service (EPREV), Radioactive Waste Services, International Nuclear Security Advisory Service (INSServ), the International Physical Protection Advisory Service (IPPAS), the IAEA State System for Accountancy and Control Advisory Service (ISSAS) and the IAEA Legislative Assistance Programme. The IAEA service INIR as a source of input is discussed separately in more detail in Section 2.2.8.

### 2.2.2. Industrial and economic infrastructure (UR2)

#### *2.2.2.1. Participation of national industry in the nuclear power programme*

The results of a study — jointly produced by the government, the owner/operator of the NES and the national industry — setting out the existing capabilities (and necessary upgrading) of the national industry to support a (planned) nuclear power programme and a State policy for the participation of national industry should be available to the INPRO assessor. In addition, the results of a cost–benefit analysis should be available, comparing the necessary investment in industrial infrastructure with the expected benefits of a nuclear power programme to national industry. The source of this information should be the responsible national government organizations such as the ministry of energy, and industry involved in the nuclear programme.

#### *2.2.2.2. Transportation of heavy equipment*

The government is usually responsible for assuring adequate means of transportation (roads, ports, bridges, etc.) of bulky nuclear components such as the reactor pressure vessel to the site of an NPP. The source of this information should be the ministry of transportation.

#### *2.2.2.3. Benefit of a nuclear power programme to society*

The results of a study should be available to the INPRO assessor that defines the (expected) benefit of the (envisaged) nuclear power programme to society in the country. The source of this information should be the responsible national government organizations such as the ministry of energy.

#### *2.2.2.4. Financial and technical constraints*

Information on financial limitations and technical constraints for the implementation of a nuclear power programme should be available as input to the INPRO assessor.

A main technical constraint may be the size of the national grid, to which an NPP will be connected. The grid size has to be compatible with the size of the NPP to be constructed. Further, the grid should represent a reliable source of power for safety sensitive equipment while the plant is shut down, e.g. for maintenance. This information should be available from the (planned) owner/operator of the NES based on an energy system expansion study. PESS provides tools and assistance in performing such an energy system expansion study on request.

In this publication, the funding of national infrastructure is taken into account[10]. Confirmation of the necessary government budget for the part of infrastructure to be covered by the State, such as educational institutions and

[10] The financing of the installation of an NES is dealt with in the economics publication [11] of the INPRO manual.

transport related measures (appropriate roads, bridges and ports), should be available to the INPRO assessor from responsible government organizations such as the ministry for transport and for education.

Based on the plan of participation of national industry in the nuclear power programme, the necessary funds for the foreseen upgrading of the national industry should be assured. Confirmation of the availability of these funds should be received from the national industry.

#### *2.2.2.5. Siting of nuclear facilities*

The siting process of nuclear facilities should be conducted taking international standards on safety, security and environment into account. The INPRO assessor should have access to relevant information on the siting process. The source of the information should be a responsible government organization, such as the regulator, the ministry of energy or the ministry of the environment. If the country has recently used the IAEA Site and External Events Design Review Service (SEED), the INPRO assessor should use the results of this service as input for the assessment.

### 2.2.3. Political support and public acceptance (UR3)

#### *2.2.3.1. Information to the public and public participation*

The INPRO assessor should have access to information about the policies of the State (ministries and regulators), of the owner/operator of nuclear facilities and of industrial companies and associations involved in a nuclear power programme regarding the provision of information to the public and mechanisms for public input into the decision making process. The information should be available from the responsible government organization, e.g. the ministry of energy, the owner/operator of nuclear facilities, and national industry.

#### *2.2.3.2. Survey of public opinion*

Finally, a survey of the opinion of decision makers and the public regarding nuclear power should have been performed by the owner/operator and the government in the country with an existing (or planned) NES, to provide input for the INPRO assessment of public acceptance of a nuclear power programme.

#### *2.2.3.3. Political environment and investor risk*

To determine the political risk of an investment in a nuclear power programme, the INPRO assessor needs information about the political situation, including the legal system dealing with interveners to nuclear projects in the country. The information should be provided by the ministry of justice.

### 2.2.4. Human resources (UR4)

#### *2.2.4.1. Educational system*

Government entities, such as regulators, the owner/operator of the NES and national industry, need adequate human resources to run a successful nuclear power programme. The INPRO assessor needs information on the (planned) national educational system and the training system of the owner/operator to provide skilled trades, technicians and professional engineers/scientists in all disciplines relevant to nuclear power. This information is to be provided by the responsible government organization such as the ministry of education and by the owner/operator.

#### *2.2.4.2. Attractiveness of nuclear power sector*

To assure the availability of qualified personnel in the nuclear power sector, the attractiveness of this sector in the country has to be confirmed. Attractiveness is based on salaries and other factors such as working conditions. The information should be provided primarily by the owner/operator of nuclear facilities.

### 2.2.5. Minimization of infrastructure (UR5)

The INPRO assessor needs information from the designer about measures to reduce the necessary national infrastructure in the new design, in comparison to an existing nuclear facility[11]. Reductions of necessary infrastructure could have been achieved by reducing the necessary human resources to operate, maintain and repair the new nuclear facility, and by using prefabrication of components during construction of a nuclear facility.

### 2.2.6. Regional and international arrangements (UR6)

There are several international arrangements available for a country with a nuclear power programme that can reduce the effort necessary to build and maintain an adequate infrastructure, such as harmonization of the licensing process, sharing of support services, application of harmonized safety standards and the use of worldwide universities for nuclear education. The INPRO assessor needs information on whether such arrangements have been considered in the planning of a nuclear power programme. The source of this information should be the responsible government organizations, such as the regulator or the ministry of education, and the owner/operator of the NES.

### 2.2.7. Assessment of innovative designs

A special situation is when an innovative[12] nuclear design in an early stage of development is to be assessed with regard to infrastructure. In such a case, new design features compared to existing (reference) designs might primarily be of interest in an INPRO assessment; in particular, the influence of these features on the amount and kind of infrastructure needed could be evaluated. This situation is most probably more relevant for an INPRO assessor in a technology holder (developer) country and less interesting for an INPRO assessor in a technology user country, as the latter will rely more on proven technology.

### 2.2.8. INIR as a source of input for a NESA in the area of infrastructure

If a country embarking on a nuclear power programme to build its first NPP is also applying — in parallel to the INPRO methodology in a NESA — the Milestone Approach [4, 5] and the corresponding INIR service from the IAEA, the INPRO assessor is recommended to contact and cooperate with the responsible national organization for the Milestone approach and INIR (usually called the NEPIO, Nuclear Energy Programme Implementing Organization [12]) to receive the necessary input for an assessment in the INPRO methodology area of infrastructure for user requirements UR1–UR4 and to harmonize the results of both activities.

Table 2 presents the issues to be covered in the Milestone approach and reviewed by the INIR process [4–6] that can provide input to the assessment of requirements of the INPRO methodology in the area of infrastructure.

[11] In this publication,‘existing facility’ is defined as ‘a facility of latest design operating 2013’.

[12] Innovative design is a design with radical changes compared to existing technology.

TABLE 2. ISSUES DEFINED IN THE MILESTONE APPROACH AND REVIEWED IN THE INIR PROCESS AND RELATED INPRO METHODOLOGY REQUIREMENTS

| User requirement (UR) in INPRO methodology | Issue (I) in INIR process |
|---|---|
| UR1: Legal and institutional infrastructure | I-1: National position<br>I-2: Nuclear safety<br>I-3: Management<br>I-5: Legislative framework<br>I-6: Safeguards<br>I-7: Regulatory framework<br>I-8: Radiation protection<br>I-13: Environmental protection<br>I-14: Emergency planning<br>I-15: Security and physical protection<br>I-17: Radioactive waste |
| UR2: Industrial and economic infrastructure | I-1: National position<br>I-3: Management<br>I-4: Funding and financing<br>I-9: Electrical grid<br>I-12: Site and supporting facilities<br>I-16: Nuclear fuel cycle<br>I-18: Industrial involvement<br>I-19: Procurement |
| UR3: Political support and public acceptance | I-1: National position<br>I-3: Management<br>I-11: Stakeholder involvement |
| UR4: Human resources | I-1: National position<br>I-3: Management<br>I-10: Human resource development |

For INPRO methodology user requirements UR5 and UR6 in the area of infrastructure, there is no direct relationship with the 19 issues of the Milestone approach process.

The relationship of a NESA and the INIR process is evaluated in more detail in the overview publication of the updated INPRO manual[13].

# 3. BASIC PRINCIPLE, USER REQUIREMENTS AND CRITERIA IN THE INPRO METHODOLOGY INFRASTRUCTURE AREA

The term 'infrastructure' within the INPRO methodology includes primarily legal and institutional measures[14], such as the establishment of a national legal framework, i.e. the conventions, laws and regulations needed for a nuclear power programme, and the corresponding organizations, e.g. the regulatory body, to fulfil the functions defined within the legal framework. An adequate national infrastructure has to be established and maintained by the national institutions of the country, meaning the government, the operators of nuclear facilities and national industry involved in a national nuclear power programme, to assure its long term sustainability.

[13] A publication on this subject is in preparation.

[14] Within the INPRO methodology, national nuclear facilities, e.g., a fuel fabrication facility or a waste storage facility, are not part of the national infrastructure, but are, by definition, components of the national NES.

In the area of infrastructure, one basic principle and six user requirements[15] have been defined. For each user requirement, several criteria have been developed, most of which have additional evaluation parameters to assist with the assessment.

## 3.1. BASIC PRINCIPLE

*Infrastructure basic principle:* A country shall be able to adopt, maintain or enlarge an NES for the supply of energy and related products without making an excessive investment in national infrastructure.

The main goal, expressed in this basic principle, is to ensure that the necessary investment in nuclear related national infrastructure is not an obstacle for the start, maintenance or expansion of a nuclear power programme.

The term ‘investment’ here is meant to cover not only direct financial investments in capital equipment but also other indirect costs, such as costs for the development of human resources, transfer of technology and know-how. The term ‘excessive’ is understood to mean economically unattractive and/or to represent an undue burden on society.

To achieve the goal of the basic principle, INPRO has developed six user requirements (UR1–UR6) directed primarily at the national institutions involved in a nuclear power programme, such as regulatory bodies, operators and nuclear industry, but also at designers of nuclear facilities.

User requirements UR1–UR4 ask national institutions involved in a nuclear power programme to achieve and maintain an adequate infrastructure, i.e. to enable a safe, secure and economical operation of an NES in the long term.

User requirement UR5 asks the designer of nuclear facilities to minimize the necessary infrastructure for a new nuclear facility by reducing the human resources needed for operation, maintenance and repair work, and to use prefabricated of components.

Additionally, user requirement UR6 asks the government and the owner/operator to consider international or regional arrangements instead of national solutions, as a means to optimize the investment in national infrastructure. One of the long term goals of the development of regional and international arrangements for nuclear related infrastructure is to reduce the necessary national investment to a level comparable to the investment in the infrastructure required for non-nuclear energy systems.

## 3.2. USER REQUIREMENT UR1: LEGAL AND INSTITUTIONAL INFRASTRUCTURE

*User requirement UR1:* An adequate legal framework should be established to cover the issues of nuclear liability, safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, security and non-proliferation.

The Fundamental Safety Principles [13] state that regulating nuclear and radiation safety and security is the responsibility of the State and that an effective legal framework must be established and maintained. The role of the INPRO assessor is to determine whether the (existing or planned) legal framework is adequate to achieve the long term sustainability of a nuclear power programme.

The establishment of a nuclear power programme entails legal requirements at both the national and international level. These requirements give rise to the need to establish and maintain a legal framework that provides the basis for establishing safety requirements for the control and oversight of operations and of security arrangements, including non-proliferation and environmental aspects. As noted, responsibility for the development and maintenance of the legal framework rests with national governments. If a country is embarking on a nuclear power programme, i.e. is planning to install its first NPP, the nuclear legal framework must be in place well in advance of the installation.

The legal framework comprises two aspects: legal requirements set out in nuclear related legislation, referred to as nuclear law, and the related institutional infrastructure including regulatory authorities that must give effect to the law and ensure that the legal requirements are met.

[15] In comparison to IAEA-TECDOC-1575/Rev.1 [1], two additional UR have been added (UR5 and UR6) that are closely linked to the goal of the BP.

In this publication, the legal framework primarily related to nuclear safety is discussed. The sustainability assessment of an NES in the area of nuclear safety, other than assessing the legal framework, is dealt with in a separate publication of the updated INPRO manual[16].

The assessment of an NES in the area of proliferation resistance, including a detailed evaluation of the legal aspects of this area, is described in a separate publication of the INPRO manual[17]. Nevertheless, in this publication, legal aspects of proliferation resistance are mentioned for completeness, primarily with the intention of assuring these aspects have been addressed in the separate assessments of proliferation resistance.

### 3.2.1. Legal framework

There are two key IAEA publications on nuclear law [14, 15]. The following information is based on these two IAEA publications. The history, evolution and outlook of nuclear law is discussed in Ref. [16].

The 2003 edition of the Handbook on Nuclear Law [14] defines nuclear law as:

> "the body of special legal norms created to regulate the conduct of legal or natural persons engaged in activities related to fissionable materials, ionizing radiation and exposure to natural sources of radiation... The primary objective of nuclear law is to provide a legal framework for conducting activities related to nuclear energy and ionizing radiation in a manner which adequately protects individuals, property and the environment."

Nuclear law has specific characteristics, such as the safety principle, the security principle and the responsibility principle, that distinguish it from other aspects of national law.

#### *3.2.1.1. Hierarchy of legislation*

Legislation is generally organized in a hierarchy of three levels: (1) constitutional instruments, (2) statutory elements enacted by a parliament or legislature, and (3) regulations promulgated by expert governmental bodies, and supplemented by so-called guidelines, i.e. non-mandatory recommendations on how to fulfil regulations. Nuclear law is part of level 2. It should primarily define requirements with the objective of ensuring public and occupational safety, environmental protection, security and non-proliferation that are binding on all persons and organizations. Nuclear law should also specify the liability regime. Regulations, a part of level 3, and guidelines are binding primarily on specific persons or organizations, e.g. the owner/operator who is licensed to operate a nuclear facility. It is recommended (see Refs [14, 15]) that regulations and especially guidelines should not be set out within nuclear law, but should be prepared by the responsible authorities, e.g. the safety authority, radiation protection authority, security body, environmental authority, to facilitate the timely updating of regulations and guidelines. (Where different authorities are involved, it is important that their activities be coordinated.)

#### *3.2.1.2. Objective of nuclear legislation*

As discussed in the IAEA Guidebook on the Introduction of Nuclear Power [17] and required in the IAEA Safety Standard Governmental, Legal and Regulatory Framework for Safety [18], nuclear legislation should seek to:

— Set out objectives for protecting individuals, society and the environment from radiation hazards;
— Vest a regulatory body[18] that is independent from public and private corporations, and institutions promoting nuclear energy and operating nuclear facilities, with legislative powers for regulating and ensuring the safe and secure use[19] of nuclear energy[20];

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[16] A publication on this subject is in preparation.

[17] A publication on this subject is in preparation.

[18] Usually consisting of a safety authority and a radiation protection authority; these could be combined in a single institution.

[19] Avoiding undue radiological risks for site personnel and the public.

[20] Covering the issue of nuclear safety and radiation protection, control of operation, security and physical protection, protection of the environment, and emergency preparedness.

— Define principles and conditions that enable the regulatory authority to authorize the carrying out of nuclear activities, such as construction, operation and decommissioning of nuclear facilities;
— Establish principles and rules consistent with international conventions on third party liability;
— Ensure the security and physical protection of nuclear and other radioactive material and facilities;
— Create a system for the accounting and control of nuclear material.

According to the IAEA Handbook on Nuclear Law [15], the objectives of nuclear law could be presented in a preamble to the law as follows:

— To permit the uses and applications of nuclear energy which are beneficial and peaceful;
— To ensure that people and the environment are adequately protected against any harmful effects that may arise from ionizing radiation and that radiation sources are kept in a safe and secure manner;
— To set up a body to regulate peaceful uses of ionizing radiation by performing the functions and holding the responsibilities detailed in nuclear law;
— To ensure that the State meets any obligations it has undertaken by signing any relevant international instruments.

*3.2.1.3. Role of conventions*

National nuclear legislation (nuclear law) should take into account regional and international treaties and conventions. To subscribe to such treaties and conventions, three steps are distinguished: signing of the convention by individual States, ratification of the convention by the State's legislative assembly/parliament and the entering into force of the convention. Individual States need to establish legal arrangements for implementing the obligations that they have assumed when signing and ratifying international instruments such as conventions (see section 1.5.9 of Ref. [14]).

In the following subsections, the legal aspects, i.e. primarily the relevant international conventions of nuclear safety and liability, non-proliferation, nuclear security, import and export control, transport of radioactive material, waste management and environmental protection are briefly discussed.

*3.2.1.4. Legal aspects of nuclear safety and liability*

Within the nuclear law, the safety of nuclear installations is an important issue. The corresponding legislation should focus on the general nuclear safety objective and the technical safety objectives [13].

Important safety related international conventions to be reflected in nuclear law include: The Convention on Nuclear Safety [19], The Joint Convention on the Safety of Spent Fuel Management and on the safety of Radioactive Waste Management [20], the Convention on Early Notification of a Nuclear Accident [21] and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency [22]. Nuclear law should reflect international best practice, as described in the IAEA Safety Standards (such as Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [23]). The concept of safety management and safety and security culture should be included either in the law or in regulations.

Nuclear law must cover the safe management of all sources and types of ionizing radiation in a country. The objective of radiation protection is to ensure that individuals, society and the environment are adequately protected against radiological hazards. Radiation protection requires that during normal operations, radiation exposures should be kept below prescribed limits and should be optimized using the ALARA[21] principle.

It is particularly important that provisions in nuclear law addressing nuclear and radiological emergency preparedness and response be carefully drafted to be consistent with other laws and arrangements for addressing other emergency situations in line with the all-hazards approach. The IAEA Safety Standard GS-R-2 [24] can be used as a basis for emergency preparedness and response provisions.

Prime responsibility for nuclear safety rests with the owner/operator of a nuclear facility. From this principle, the nuclear liability regime has been derived (see Chapter 11 of Refs [14, 15]). The basic idea behind the term

[21] ALARA means as low as reasonably achievable, social and economic factors being taken into account [29].

liability is that a person or entity responsible for causing harm should compensate the victim. States recognized at an early stage that the possibility of transboundary damage required an international nuclear liability regime.

The nuclear liability regime is based on two basic conventions: The Paris Convention (adopted in 1960 under the auspices of the OECD Nuclear Energy Agency (OECD NEA) came into force in 1968 [25]) and the Vienna Convention (adopted in 1963 under the auspices of the IAEA, came into force in 1977 [26]). The Paris Convention provides a third party liability regime and is open to OECD states. It was amended in 1963 by the Brussels Supplementary Convention (further compensation by public funds).[22] The Vienna Convention established a worldwide system and was supplemented in 1997 by the Convention on Supplementary Compensation for Nuclear Damage [27]. In 1988 the Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention [28] was established.[23]

In all nuclear liability regimes (with the exception of Austria and the United States of America), the concept of strict liability is applied, i.e. the owner/operator of a nuclear installation is held liable regardless of fault. Further, the simple existence of causation of damage is the basis of the operator's liability. Additional principles of nuclear liability are the limitation of liability in amount and time, (recognizing that civil law is not designed to cope with catastrophes and that in the event of such a catastrophe, the State will inevitably step in and pay additional compensation) and the concentrations of procedures within a single court (to create legal certainty).

#### *3.2.1.5. Legal aspects of non-proliferation*

The most significant international treaty in the area of non-proliferation is the Treaty on the Non Proliferation of Nuclear Weapons (the NPT, [30]). To ensure compliance with the basic commitments (not to transfer or to acquire nuclear weapons) of the NPT, all non-nuclear-weapon States accept safeguards for the purpose of verification of the fulfilment of their obligations (Chapter 12 of Refs [14, 15]) based on a comprehensive safeguards agreement and additional protocols[24].

The foundation of the safeguards system lies in the IAEA Statute, which is binding on both the IAEA Secretariat and IAEA Member States. Safeguards comprise three main functions: accountancy, containment and surveillance, and inspection.

Supplementary to the NPT, several regional non-proliferation agreements exist, such as the Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean (Treaty of Tlatelolco), the South Pacific Nuclear Free Zone Treaty (the Rarotonga Treaty), the Treaty on the Southeast Asia Nuclear Weapon-Free Zone (the Bangkok Treaty) and the African Nuclear-Weapon-Free Zone Treaty (the Pelindaba treaty).

A State system for accounting and control of nuclear material (SSAC) is an important part of the non-proliferation regime. Further details on this regime can be found in the proliferation resistance manual of the INPRO methodology[25].

#### *3.2.1.6. Legal aspects of nuclear security*

The main international conventions in this area are, firstly, the Convention on the Physical Protection of Nuclear Material [31] and its 2005 amendment [32] and, secondly, the International Convention for the Suppression of Acts of Nuclear Terrorism [33]. Additional international legal instruments relevant for this area are: United Nations Security Council resolution 1373 [34] on threats to international peace and security caused by terrorist acts; United Nations Security Council resolution 1540 [35] on the non-proliferation of weapons of mass destruction; The Code of Conduct on the Safety and Security of Radioactive Sources [36] and the companion publication Guidance on the Import and Export of Radioactive Sources [37]; The Protocol to the Convention for the Suppression of

[22] There are two additional protocols which, at the time of writing had not yet come into force: The Protocol of 12 February 2004 to the 1960 Paris Convention (2004 Paris Convention) and the Protocol of 12 February 2004 to the 1963 Brussels Supplementary Convention (2004 Brussels Supplementary Convention) concluded under OECD auspices and open to OECD Member States.

[23] There is also The Convention on Supplementary Compensation for Nuclear Damage (1997 CSC), concluded under IAEA auspices and open to all Parties to the Paris and Vienna Conventions and to States which are Party to neither the Paris nor the Vienna Convention but have domestic legislation in place which is consistent with the principles embodied in those conventions. The 1997 CSC had not entered into force at the time of writing.

[24] Requirements for so-called Small Quantities Protocols were modified in 2005 by the IAEA (see Ref. [16]).

[25] A publication on this subject is in preparation.

Unlawful Acts against the Safety of Maritime Navigation (SUA Convention) [38]; and The Protocol of 2005 to the Protocol for the Suppression of Unlawful Acts against the Safety of Fixed Platforms Located on the Continental Shelf [39].

Further details on this regime can be found in Chapter 14 of Refs [14, 15] and in the IAEA Nuclear Security Series publications [40–48].

*3.2.1.7. Legal aspects of import and export control*

As stated in Chapter 13 of the IAEA Handbook on Nuclear Law [15], export and import controls are relevant to safety, nuclear security and safeguards measures in a State and enable it to maintain its sovereign control over activities taking place within its own territory. Export controls help to prevent the spread of nuclear weapons and nuclear explosive devices. They are required under relevant multilateral and regional nuclear non-proliferation instruments, most prominently the NPT [30], and the reporting of certain exports and imports to the IAEA is required under safeguards agreements negotiated in connection with such instruments. From a nuclear security perspective, both export and import controls are relevant to preventing and detecting illicit trafficking, and can help to prevent the acquisition of nuclear and other radioactive materials by persons or entities that could seek to use them for malicious purposes. Export and import controls also contribute to safety by helping States to ensure that exported or imported items are only acquired by persons or entities with the capability of using them in an acceptable manner and only for authorized purposes.

*3.2.1.8. Legal aspects of the transport of radioactive material*

As stated in Chapter 9 of the IAEA Handbook on Nuclear Law [15], the IAEA regularly publishes detailed Regulations for the Safe Transport of Radioactive Material (the transport regulations) [49] addressing all categories of radioactive material. Also, in May 2005 the IAEA Board of Governors approved a new policy for reviewing and revising the transport regulations. According to this policy, the IAEA Secretariat will continue to review the transport regulations at intervals consistent with the schedules of the United Nations Sub-Committee of Experts on the Transport of Dangerous Goods and of the relevant international modal organizations in order to remain in step with the review cycles of the other relevant international bodies.

*3.2.1.9. Legal aspects of radioactive waste management*

As stated in Chapter 10 of the Handbook on Nuclear Law [14], notwithstanding differences in national development policies on the treatment of radioactive waste and spent fuel, States utilizing nuclear energy have been able to reach a consensus on the basic principles that should be applied in the field of radioactive waste and spent fuel management. This consensus is reflected in the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) [20].

*3.2.1.10. Legal aspects of environmental protection*

There is a convention regarding environmental issues in transnational situations, the Convention on Environmental Impact Assessment in a Transboundary Context (the Espoo convention) [50], adopted in 1991 by the United Nations Economic Commission for Europe (UNECE) in the Finnish city of Espoo. Environmental threats do not respect national borders. Governments have realized that to avert this danger they must notify and consult each other on all major projects under consideration (including nuclear power) that might have adverse environmental impact across borders. The Convention entered into force in 1997. There is also an additional protocol to this Convention, the Protocol on Strategic Environmental Assessment (SEA), that was adopted in 2003. The SEA Protocol augments the Espoo Convention by ensuring that individual Parties integrate environmental assessment into their plans and programmes at the earliest stages. The SEA Protocol entered into force on 11 July 2010. This convention and its protocol are also applicable to the (planned) installation of an NPP.

### 3.2.2. Institutional infrastructure

The term institutional infrastructure in the INPRO methodology covers all regulatory authorities that need to be established and maintained by a country for a long term sustainable nuclear power programme, with regard to nuclear safety, environment, security, non-proliferation, export and import control, transport of radioactive material and radioactive waste management. In addition, for the development of adequate human resources, an infrastructure for education and training is needed.

#### *3.2.2.1. Safety and environmental institutions*

The institutional infrastructure in regard to nuclear safety consists primarily of a regulatory body empowered by nuclear law (see Chapter 2 of Refs [14, 15]). Preferably, this regulatory body should be a single institution covering all regulatory aspects of nuclear safety, including regulation of the management of radioactive waste and spent fuel. In some countries, however, there are two authorities, the nuclear safety authority and the radiation protection authority, and there are examples where some specific aspects of nuclear safety, such as the safe transport of radioactive material, is the responsibility of a different governmental organization, e.g. the ministry of transportation, and import and export control is the responsibility of the ministry for economy. Additionally, most States will have an environmental authority that may impose additional requirements on nuclear facilities, such as the fulfilment of the Espoo convention mentioned above. In such cases of divided responsibility, the responsibilities and functions of each organization must be clearly defined and their activities must be coordinated and harmonized.

For countries embarking on a nuclear power programme, the IAEA has developed Specific Safety Guide No. SSG-16, Establishing the Safety Infrastructure for a Nuclear Power Programme [51]. This publication defines the necessary actions to be taken during the development of a nuclear programme to achieve an adequate nuclear safety infrastructure, and references the applicable IAEA safety requirements.

#### *3.2.2.2. Security institutions*

Within a national security regime, several State organizations in a country are required to work together, each with well-defined responsibilities. In addition to the security department of the owner/operator of a nuclear facility, organizations with responsibilities for specific aspects of nuclear security include local authorities in the area of the facility (e.g. local police), and State organizations (e.g. the military, intelligence agencies, national police). A competent State authority must be in place to ensure the establishment and maintenance of the security of nuclear material and nuclear facilities, as well as a national security regime that, inter alia, will ensure the fulfilment of the commitments resulting from adherence to applicable international nuclear security conventions. Further details on this issue can be found in the respective chapter 14 of Refs [14, 15] and in the IAEA Nuclear Security Series publications [40–48].

#### *3.2.2.3. Non-proliferation institutions*

While safety and security are national responsibilities, non-proliferation is both a national and an international responsibility. The responsible international authority is the IAEA. Having said that, States must ensure that there is a national safeguards authority to ensure that the State is fulfilling its obligations under the NPT [30], as set out in the comprehensive safeguards agreement [52] and additional protocols [53] between the State and the IAEA (see Chapter 12 of Refs [14, 15]). One of the most important responsibilities of a national safeguards authority is to establish and maintain the SSAC. Further details on this issue can be found in the proliferation resistance manual of the INPRO methodology[25].

#### *3.2.2.4. Institutions for disposal of radioactive waste and spent fuel*

In most countries with a nuclear power programme, there is a government organization — separate from the owner/operator of nuclear facilities — that is responsible for the management and disposal of radioactive waste and spent fuel. To enable safe disposal, this organization would be in charge of defining the end state (and all intermediate steps) of all nuclear wastes produced in the national NES. This issue is further discussed in the waste management publication of the INPRO manual[26] and in Chapter 10 of Refs [14, 15].

*3.2.2.5. Institutions for education and training*

To operate and regulate a successful nuclear power programme requires a qualified workforce. For a nuclear power programme, engineers, technicians and skilled trades/craftsmen are primarily needed. A variety of educational institutions have a role to play in building and maintaining a skilled workforce, including universities (e.g. with nuclear engineering courses) and technical schools with access to specialized training facilities (e.g. for training nuclear operators, qualifying welders and non-destructive testing experts). Training centres could also be run by the operator of the nuclear facility. This topic is discussed further, in Section 3.5, when addressing user requirement UR4 (human resources).

INPRO has defined two logical criteria for UR1 as set out in Table 3. In the following subsections, guidance is provided on evaluating these two criteria CR1.1 and CR1.2.

TABLE 3. CRITERIA OF USER REQUIREMENT UR1

| User requirement | Criteria | Indicators (IN) and acceptance limits (AL) |
|---|---|---|
| UR1 Legal and institutional infrastructure:<br><br>An adequate legal framework should be established to cover the issues of nuclear liability, safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, security and non-proliferation | CR1.1: Legal aspects | IN1.1: Status of legal framework<br><br>AL1.1: Legal framework has been established, in accordance with international standards |
| | CR1.2: Institutions | IN1.2: Status of State organizations with responsibilities for safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, emergency preparedness and response, security and non-proliferation<br><br>AL1.2: State organizations have been established, in accordance with international standards |

### 3.2.3. Criterion CR1.1: Legal aspects

*Indicator IN1.1:* Status of legal framework.
*Acceptance limit AL1.1:* Legal framework has been established, in accordance with international standards.

This criterion deals with the establishment of an adequate nuclear legal framework consisting of a nuclear law and corresponding regulations (rules) and associated guidelines. The necessary content of such a legal framework has been discussed briefly above. A comprehensive description of the legislative process to create an adequate nuclear law and its content, requirements and history can be found in Refs [14, 15]). Using this reference, a set of evaluation parameters has been identified by the INPRO methodology, as a sublevel of criterion CR1.1.

*3.2.3.1. Evaluation parameter EP1.1.1: Scope of nuclear law*

Nuclear law should cover the following areas:

— Establishment of the regulatory body with its responsibilities, such as authorization/licensing, inspection and enforcement;

[26] A publication on this subject is in preparation.

— Radiation protection;
— Safety of nuclear installations;
— Emergency preparedness and response;
— Radioactive material and radiation sources;
— Transport of radioactive material;
— Management of radioactive waste and spent fuel;
— Mining and milling, if such activities take place in the given country;
— Nuclear liability and coverage;
— Export and import controls for nuclear material;
— Safeguards for nuclear material which assure non-proliferation;
— Nuclear security;
— Environmental protection, if not covered elsewhere in the laws of the State.

Acceptability of EP1.1.1 (condition for a positive judgement): Evidence is available to the INPRO assessor that all areas listed above are covered by the national nuclear law.

*3.2.3.2. Evaluation parameter EP1.1.2: Adequacy of nuclear law*

To assess whether an established nuclear law is adequate in accordance with international standards, the following questions (taken from the Handbook on Nuclear Law, Section 1.5.2 of Ref. [14]) could be used by an INPRO assessor with a background in nuclear law:

“(a) Does the current legislation make it clear that public health, safety, security and the environment are overriding considerations in the use of nuclear techniques and material?
(b) Are there major gaps or overlaps in the legal structure regarding the treatment of nuclear related activities or material, both those currently being conducted or used and those that can reasonably be expected?
(c) Have the most important terms used in the legislation been given clear and consistent definitions in the statutory documents? Does the use of different terms and definitions, or a failure to define certain terms, produce confusion about how nuclear related activities are to be regulated?
(d) Are the institutional responsibilities for regulating nuclear related activities clear and consistent, permitting efficient regulation without delays and bureaucratic conflicts?...
(f) Does the present system fully comply with the State’s international legal obligations and reflect international best practice, as described in safety standards…promulgated by the IAEA or other relevant multinational bodies?”

Acceptability of EP1.1.2 (conditions for a positive judgement): Evidence is available to the INPRO assessor that the questions above have been answered satisfactorily, i.e. an affirmative answer (YES) for questions (a), (c) (first part), (d) and (f); and a negative answer (NO) to the questions (b) and (c) (second part).

Alternatively, an INPRO assessor could use the results of an IAEA service from the Office of Legal Affairs (OLA) called the IAEA Legislative Assistance Programme to confirm the adequacy of the existing (or planned) national nuclear law.

*3.2.3.3. Evaluation parameter EP1.1.3: International legal arrangements*

Individual States need to establish national legal arrangements for implementing the obligations that they have assumed when signing and ratifying international instruments such as conventions. The IAEA Handbook on Nuclear Law (in section 1.5.10 of Ref. [14] and in chapter 1 of Ref. [15]) discusses general approaches, i.e. transformation and incorporation, that can be followed when adopting the standards and guidelines of international organizations or of other States in a national legal framework.

INPRO recommends that States sign, ratify and put into force established regional and international conventions and treaties to the extent possible, including at least the following international instruments, amended or enlarged:

- — Convention on Nuclear Safety [19];
- — International Nuclear Liability convention [25, 26];
- — Convention on Early Notification of a Nuclear Accident [21];
- — Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency [22];
- — Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [20];
- — Treaty on the Non-Proliferation of Nuclear Weapons (NPT) (and associated safeguards agreements and protocols) [30];
- — Convention on Physical Protection of Nuclear Material [31];
- — Code of Conduct on the Safety and Security of Radioactive Sources [36];
- — International Convention for the Suppression of Acts of Nuclear Terrorism [33];
- — The Espoo convention [50].

Acceptability of EP1.1.3 (condition for a positive judgement): Evidence is available to the INPRO assessor that all the above defined international legislation has been signed and ratified, and incorporated into national nuclear law, i.e. legal arrangements for implementing the obligations that the State has assumed when signing and ratifying these international instruments have been established.

*3.2.3.4. Evaluation parameter EP1.1.4: Completeness and adequacy of regulations and guidelines*

As part of the legal framework, the third level (see Section 3.2.1.1) of the legal requirements, consisting of regulations and associated guidelines, has to be established.

INPRO methodology recommends that the national regulatory body should take into account established international safety standards when creating this additional level in the area of nuclear safety (e.g. Refs [13, 23]). For the area of nuclear security, similar international guideline publications are available [40–48].

Acceptability of EP1.1.4 (condition for a positive judgement): Evidence is available to the INPRO assessor that national regulations and guidelines are consistent with and take into account international standards.

A country embarking on a nuclear power programme can follow the approach presented in Refs [51, 54] that provide guidance on the establishment of a framework for safety in accordance with the IAEA safety standards.

*3.2.3.5. Final assessment of criterion CR1.1: Legal aspects*

The acceptance limit AL1.1 (Legal framework has been established, in accordance with international standards) of criterion CR1.1 is met when the evaluation of each of the four EPs (EP1.1.1–EP1.1.4) provides a positive judgement.

When assessing compliance with criterion CR1.1, INPRO recommends that the INPRO assessor obtains assistance from relevant departments of competent international organizations such as the IAEA.

### 3.2.4. Criterion CR1.2: Institutions

*Indicator IN1.2*: Status of State organizations with responsibilities for safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, emergency preparedness and response, security and non-proliferation.
*Acceptance limit AL1.2:* State organizations have been established, in accordance with international standards.

The second criterion CR1.2 of UR1 deals with the institutional aspects of the legal framework related to regulatory bodies (the other institutions in the responsibility of the government (e.g., for education/training) are discussed in UR4). To carry out its responsibility effectively, efficiently and independently, the regulatory body needs to be provided with adequate personnel, financial resources, office quarters, information technology and support services. In deciding on the structure of the regulatory body, the country's cultural attitudes and traditions, the nature of its national legal infrastructure and the established governmental organizations with their procedures have to be taken into account; as well as technical, financial and human resources available within the State and/or accessible regionally or internationally.

To assess important attributes of the regulatory body, several evaluation parameters (EP1.2.1 to EP1.2.7) have been chosen and are discussed below.

*3.2.4.1. Evaluation parameter EP1.2.1: Independence of the regulatory body*

An important attribute of a regulatory body is that it shall be independent from interference in its regulatory functions by operators of nuclear facilities or institutions with a role in promoting nuclear energy (Ref. [55] and Principle 2 of the Safety Fundamentals [13]). In situations where the regulatory body is relying on advisory bodies (or technical support organizations, TSO) for fulfilling some of its functions, these institutions should also be independent. The basis for such independence should be set out in the nuclear law (see Chapter 2.4 of Ref. [15]). In addition to financial independence, effective independence depends on factors such as technical and managerial competence, adequacy of human resources, effective leadership, the process used for appointing the head of the regulatory body, and enforcement and reporting mechanisms, including the reporting of safety related incidents in nuclear facilities. Recognized means of achieving such effective regulatory independence (Chapter 2 of Ref. [15]) include: Institutional separation of regulatory and non-regulatory functions; fixed terms for regulatory officials; constraints on the removal of regulatory officials on political grounds; separate budgetary and employment authority for the regulatory body; reporting to an official or organization without conflicting responsibilities; and unrestricted access to the press and the public.

Acceptability of EP1.2.1 (condition for a positive judgement): Evidence is available to the INPRO assessor of the adequacy of the human resources of the regulatory body and of its competence and capability to achieve and maintain positions independent of the owners/operators of nuclear facilities, and that it is free from undue pressure from interested parties — commercial or political.

*3.2.4.2. Evaluation parameter EP1.2.2: General functions of the regulatory body*

The main activities or functions of the regulator body are summarized below (see Section 3.2 of Ref. [5] and Section 2.3 of Refs [14, 15]):

- Establishment of regulatory standards, codes and criteria, and guidelines for the design, construction, operation and decommissioning of nuclear facilities, including the safe and secure management of radioactive wastes generated;
- Review and evaluation of licensing documents, such as the nuclear security and contingency plans, safety analysis and environmental reports of nuclear facilities and on-site emergency arrangements;
- Authorization of the construction, operation and decommissioning of a nuclear facility and the conduct of activities by a licensee, by e.g. issuing licenses, registration;
- Performance of inspections, reviews, audits and enforcement activities to ensure compliance with established rules and regulations;
- Provision of information about safety and security aspects of facilities and activities to the public, the media and interested parties;
- Coordination with other regulatory bodies.

In appendix I of Ref. [56], 14 characteristics of a fully functional and effective regulatory body are defined that could be used to evaluate the adequacy of a regulatory body. To assess evaluation parameter EP1.2.3, INPRO methodology recommends using the support of relevant departments of qualified organizations such as the IAEA.

Acceptability of EP1.2.2 (condition for a positive judgement): This evaluation parameter can be considered fulfilled if there is evidence available to the INPRO assessor of the adequate performance of these functions by all regulatory bodies involved in a nuclear power programme.

*3.2.4.3. Evaluation parameter EP1.2.3: Review of safety regime*

The evaluation parameter calls for an effective and efficient safety regime. Thus, evidence is required that a review of the national safety regime has been carried out by a competent organization and that the results of the review are positive.

To evaluate evaluation parameter EP1.2.3, INPRO methodology recommends using the support of relevant departments of qualified organizations such as the IAEA. For example, the IAEA offers, on the request of a government, an IRRS to evaluate a country's existing or planned regulatory arrangements regarding nuclear and radiation safety. The IRRS mission is designed to strengthen and enhance the effectiveness of the national regulatory infrastructure of States for nuclear, radiation, radioactive waste and transport safety and security of radioactive sources, while recognizing the ultimate responsibility of each State to ensure safety in the above areas. This expressed purpose of the IRRS is to be accomplished through consideration of both regulatory technical and policy issues, with comparisons against IAEA safety standards and where appropriate, good practices elsewhere.

Acceptability of EP1.2.3 (condition for a positive judgement): Evidence is available to the INPRO assessor that a review of the nuclear safety regime has been carried out by a competent institution with positive results.

*3.2.4.4. Evaluation parameter EP1.2.4: Review of emergency preparedness*

Nuclear and radiological emergency preparedness can be considered to be a component of a nuclear safety regime but, because of its importance and because in some States nuclear and radiological emergency preparedness is a subset of emergency preparedness in general, here nuclear and radiological emergency preparedness is considered separately.

Number 9 of the Fundamental Safety Principles [13] states that arrangements must be established for preparedness and response for nuclear or radiological emergencies.

The practical goal of emergency preparedness, as defined in the IAEA Safety Standard on Preparedness and Response for a Nuclear or Radiological Emergency [24], is to ensure that arrangements are in place for a timely, managed, controlled, coordinated and effective response at the scene, and at the local, regional, national and international level, to any nuclear or radiological emergency.

The practical goals of emergency response are [24]:

— To regain control of the situation;
— To prevent or mitigate consequences at the scene;
— To prevent the occurrence of deterministic health effects in workers and the public;
— To render first aid and to manage the treatment of radiation injuries;
— To prevent, to the extent practicable, the occurrence of stochastic health effects in the population;
— To prevent, to the extent practicable, the occurrence of non-radiological effects on individuals and among the population;
— To protect, to the extent practicable, property and the environment;
— To prepare, to the extent practicable, for the resumption of normal social and economic activity.

The government must ensure that adequate arrangements are put in place to prepare for and to respond to a nuclear or radiological emergency at the operating organization, local, regional and national levels and, where appropriate, at the international level. On-site emergency arrangements for preparedness to respond to an emergency at a facility under the responsibility of an operating organization are to be dealt through the regulatory process. This includes review and approval of the on-site emergency arrangements of the operating organization by the regulatory body as part of the licensing process. The scope and extent of emergency arrangements will depend on the results of the hazard assessment[27] to be carried out in line with Ref. [24].

An IAEA publication within the Emergency Preparedness and Response (EPR) Series, on a Method for Developing Arrangements for Response to a Nuclear or Radiological Emergency [57], presents a practical, step by step method for developing arrangements for preparedness to respond to a nuclear or radiological emergency at operating organization, local and national level in line with Ref. [24]. Another publication within the EPR Series,

[27] Referred to as threat assessment in Ref. [24].

Considerations in Emergency Preparedness and Response for a State Embarking on a Nuclear Power Programme [58], is intended to assist those States that are embarking on a nuclear power programme to develop prior to commissioning their first NPP an adequate level for emergency preparedness to respond to a nuclear or radiological emergency. Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor [59] is another publication within the EPR Series that provides those responsible for making and for acting on decisions in the event of a nuclear or radiological emergency with guidance on the actions necessary to protect the public involving actual or projected severe damage to the fuel in the reactor core or spent fuel pool at a light water reactor (LWR) or spent fuel pool.

Upon their request, the IAEA can assist Member States in conducting an independent assessment of the arrangements and capabilities for preparedness and response for nuclear and/or radiological emergencies through the EPREV (Emergency Preparedness Review) appraisal service. The EPREV service offers various types of missions to Member States covering all aspects from the appraisal of the emergency preparedness arrangements at a specific installation to a full appraisal of all arrangements in a requesting Member State, including on-site, off-site and national arrangements.

Acceptability of EP1.2.4 (condition for a positive judgement): A review of the emergency preparedness arrangements has been carried out either by a competent independent national authority, such as the regulator, or government auditor or by competent international organizations, such as the IAEA, with results that assure the adequacy of the level of preparedness. Results of such a review and the subsequent follow-up actions taken should be available to the INPRO assessor.

#### *3.2.4.5. Evaluation parameter EP1.2.5: Review of nuclear security regime*

The evaluation of parameter EP1.2.5 calls for an effective and efficient nuclear security regime. Thus, evidence is required that a review of the nuclear security regime has been carried out by a competent organization and that the results of the review are positive. Such a review may have been carried out by domestic organizations such as the government's national audit office.

The IAEA could also be requested to provide assistance in performing such a review. To assist States in the identification of the best means by which to strengthen their nuclear security regime, the IAEA has initiated INSServ. INSServ missions requested by a State aim at assisting the State to identify, in a holistic manner, the scope of concerns to be addressed by the nuclear security regime, including the security of nuclear material and facilities, of radioactive sources, and detection and response to illicit trafficking (for assistance, the IAEA should be contacted).

Upon request, the IAEA can also assist Member States in strengthening and enhancing the effectiveness of the nuclear security of materials and facilities through IPPAS missions. The IPPAS mission could be conducted on a State-wide basis or could be facility specific. During an IPPAS mission, the State's regulatory system for the protection of nuclear facilities is reviewed as well as the resulting physical facility protection systems. Advice is offered, based on international guidelines [47] and internationally recognized best practices to assist the State as it protects nuclear material and facilities.

Acceptability of EP1.2.5 (condition for a positive judgement): Evidence is available to the INPRO assessor that the review of the nuclear security regime by a competent organization has confirmed the adequacy of the regime.

#### *3.2.4.6. Evaluation parameter EP1.2.6: Review of safeguards regime*

INPRO methodology has defined a detailed assessment process for the safeguards regime of a country (in the proliferation resistance manual of the INPRO methodology). Here, the evaluation parameter EP1.2.6 is defined, primarily to assure that an adequate assessment of the safeguards regime is to be performed as part of the holistic assessment of an NES.

The IAEA offers a service to Member States called ISSACS. The ISSACS mission provides requesting national authorities with recommendations and suggestions for improvements to their State systems for accountancy and control (SSACs) of nuclear material. The missions evaluate the regulatory, legislative, administrative and technical components of the SSAC at both the State and facility level, and assess how the SSAC meets the obligations contained in the State's safeguards agreement and additional protocol as applicable.

Acceptability of EP1.2.6 (condition for a positive judgement): Evidence is available to the INPRO assessor that a review of the non-proliferation regime by a competent organization has confirmed the adequacy of the regime.

*3.2.4.7. Evaluation parameter EP1.2.7: Management system*

A management system should be established in all institutions related to a nuclear power programme to ensure that defined quality goals and objectives are met and implemented for all processes important to safety, security, proliferation resistance and environment. To establish and maintain such a programme, the IAEA guidance on management systems in Refs [60, 61] can be used.

Acceptability of EP1.2.7 (condition for a positive judgement): Evidence is available to the INPRO assessor that a quality assurance policy has been defined and implemented in all institutions related to a nuclear power programme.

*3.2.4.8. Final assessment of criterion CR1.2: Institutions*

The acceptance limit AL1.2 (State organizations with responsibilities for safety and radiation protection, environmental protection, control of operation, waste management and decommissioning, security and non-proliferation have been established, in accordance with international standards) of CR1.2 is met only when the assessment of all evaluation parameters (EP1.2.1 to EP1.2.7) discussed above produced a positive judgement.

## 3.3. USER REQUIREMENT UR2 ECONOMIC AND INDUSTRIAL INFRASTRUCTURE

*User requirement UR2:* The industrial and economic infrastructure of a country with an NES should be adequate to support the project throughout the complete lifetime of the nuclear power programme, including planning, construction, operation, decommissioning and related waste management activities.

This user requirement refers to the necessary industrial and economic infrastructure to be available or established within a country that is intending to install, maintain or enlarge a nuclear power programme. While user requirement UR2 is focused on the role of national industry in supporting the owner/operator of nuclear facilities, it needs to be recognized that State infrastructure, for example, in the area of transportation, is encompassed by this requirement.

A key reference for industrial infrastructure is the IAEA publication Developing Industrial Infrastructure to Support a Programme of Nuclear Power [62][28].

The role of the INPRO assessor is to check whether the established or planned industrial and economic infrastructure is adequate.

### 3.3.1. Support of infrastructure by national industry and government

*3.3.1.1. Industrial support infrastructure*

In the ideal case, a complete domestic industrial infrastructure would enable a given country to perform all activities during the lifetime of a nuclear power programme, such as the planning, design, component manufacture, construction and installation, maintenance and repair, and decommissioning of nuclear facilities and the management of related radioactive wastes. The corresponding industrial capabilities required to perform these activities are very broad. They include the availability of skilled and qualified human resources; the supply of materials, semifinished products, standard and specialized equipment; and the availability of means for transporting goods and supplies. The supply of materials includes the supply of products such as cement and steel. Semifinished products include items such as piping, tubing, plates, etc. Standard equipment includes parts such as cables and electrical equipment such as motors, etc. Special equipment includes nuclear components and also equipment for machining large components, bending and forming, boring, forging, welding and surface treatment. The manufacturing of special nuclear components (e.g. pressure vessels, steam generators, main coolant pumps) is challenging and their supply

[28] A revised version of this publication is in preparation.

should be optimized by evaluating international supply options. Special equipment may be needed for shipments made by road, railway, air and ship and to lift heavy and bulky components.

It is highly unlikely that any country will have a complete domestic capability — at least some components or materials will have to be imported. For a country acquiring its first NPP, many components will be imported and the scope for domestic supply will be limited. For subsequent units, the scope of domestic supply would be expected to increase as the country acquires capability.

A country embarking on a nuclear power programme should include in its planning phase, as part of a feasibility study, a survey of existing national industrial capabilities (see, for example, section 5.8.3 of Ref. [17]). Such a survey would identify the needs and opportunities for upgrading the national industry, which are typically relevant in three areas: manufacturing, engineering and quality management (quality assurance and quality control).

Based on the results of the survey, a plan for the development of national participation should be established. This plan would seek to define an optimized level of participation as a function of the status of the nuclear power programme, taking into consideration national policy objectives and the capabilities and development potential of domestic industry. Government and the owner/operator of the nuclear facility can play an important role in enhancing the domestic industrial infrastructure, by supporting industry with a combination of political, technical and organizational measures, for example, by providing financial support for upgrading capabilities or by adopting a policy that favours local suppliers.

An optimum level of domestic participation in a nuclear power programme will evolve with time. For example, assuming that several units are to be constructed, it could progress as follows (see section 10.2.3 of Refs [7, 63]):

- Domestic labour and some construction materials obtained from national suppliers are used for non-specialized purposes on-site, especially civil engineering works.
- Domestic contractors assume responsibility, full or partial, for the civil engineering work, possibly including some design work.
- Domestically manufactured components from existing factories are used for non-critical parts of the balance of plant.
- Domestic manufacturers extend their production capabilities to manufacture components that meet nuclear standards, possibly under licensing arrangements with foreign suppliers.
- Domestic manufacturing facilities are set-up to manufacture specialized heavy and other nuclear components, possibly under licensing arrangements with foreign suppliers.

Investment in and the extent to which national capabilities are developed needs to take into account the scope of the planned nuclear programme. A successful implementation of such a progressive national participation in a nuclear power programme has taken place in the Republic of Korea [63, 64].

*3.3.1.2. Governmental support infrastructure*

The government has a role in providing buildings (office space) and equipment for institutions needed for a nuclear programme, such as the regulatory bodies, laboratories for research and testing, and facilities for education and training. In the area of transportation, the availability of adequate roads, bridges, ports and airports is also the responsibility of the government, to enable the transport of nuclear components, some of them of large volume and weight (e.g. reactor pressure vessel).

### 3.3.2. Economic infrastructure

In this publication of the INPRO manual, economic aspects related to the national infrastructure[29] needed to start up, maintain or expand a nuclear power programme are discussed. Economic infrastructure is understood as the capabilities of government and national industry to raise the capital needed for their investments into nuclear related infrastructure.

[29] The general economic aspects of an NES installation are dealt with in the economics publication of the INPRO manual [11]. In Ref. [11], the competitiveness of nuclear power is evaluated by comparison with other energy sources. The costs of electricity production (or other energy products) from nuclear power must be competitive, and the needed investment must be raised.

*3.3.2.1. Infrastructure investments by the government*

As discussed earlier (UR1), one of the prime responsibilities of government within a nuclear power programme is to establish and maintain a regulatory body responsible for safety and radiation protection (including emergency preparedness), security, non-proliferation and environment.

As stated above, a government would be expected to foster, together with industry, educational centres for the development and training of human resources, e.g. nuclear engineering courses, possibly including nuclear R&D facilities. Further, government investment may be required to upgrade the national infrastructure needed for transporting nuclear components, such as ports, roads and bridges, owing to the size of some components of nuclear facilities such as the reactor pressure vessel.

These necessary investments in infrastructure may require substantial financing resources from the government and may involve adjustments to the country's national budget. The costs of establishing and maintaining the requisite institutions and activities may not be completely covered by taxes included in the tariff for energy products (e.g. electricity) and could become partly external costs, which would, in the long run, be balanced by spin-off benefits, including the benefit to society that results from the availability of an affordable and reliable supply of energy. This topic is discussed further when considering criterion CR2.5.

*3.3.2.2. Infrastructure investments by national industry*

If national industry is to participate in a nuclear power programme, as discussed above, it will need to invest, for example, to acquire new machinery, to train its staff in new technical processes, to add quality assurance and control procedures, and to expand its human resources. Substantial investments may be required even when technology is transferred, for example under a licensing agreement. (The staffing costs of the utility are internalized, i.e. included in the price of electricity or other energy products, e.g. heat.) Such investments by industry may represent a significant financing challenge and some government support may be required. While spin-off benefits such as the capability of manufacturing to higher quality standards may be significant, industry would seek an adequate financial return on its investment from the sale of products to the nuclear power programme. Thus, the industrial investment costs would be reflected in the costs to the owner/operator of the products and would, in the end, be reflected in the cost of power produced by the NPP, which is an indicator in the INPRO methodology area of economics (see the economics publication of the INPRO manual [11]). Note that the national plan for the participation of domestic industry needs to consider the investment needed for a given level of participation to determine if the investment is justified by the planned nuclear power programme, i.e. taking into account the number of plants to be acquired and the schedule for their introduction.

*3.3.2.3. National electricity grid*

For technical reasons (grid stability, the flexibility needed for matching supply to daily, weekly and annual load cycles), the size of a new NPP must be compatible with the grid to which it is to be connected [65]. The technical requirement that an NPP that is to be added to a grid represent no more than about 10% of the peak demand serviced by the grid would only be satisfied if there were significantly greater demand for power than that which can be delivered by the new NPP. Thus, the technical requirement for unit size and the economic requirement that there is a market for the product are mutually compatible.

*3.3.2.4. Types of contract for acquiring a nuclear facility*

The type of contract for the supply of an NPP or any other component of the nuclear fuel cycle (Section 11.4 of Ref. [17]) chosen by an owner/operator, which could be strongly influenced by government policy, has a strong impact on the requirements for national industrial infrastructure.

Basically, three main types of contract approach have been used in the past for all nuclear power projects:

Turnkey: A single contractor or a consortium of contractors takes over the responsibility for the complete project, including all parts and all phases, such as design, engineering, project management, construction, erection and supply of installations, testing and commissioning. The contractor, or the main contractor in the case of a consortium, is fully responsible for completing the plant on schedule and for meeting specific technical requirements, e.g. power output, efficiency, etc., at an agreed price.

- Split package: The overall responsibility is divided among a small number of contractors, each in charge of a large section of the work. An architect-engineer has to be involved to coordinate the project.
- Multiple packages: The owner/operator, possibly supported by an architect-engineer, assumes the overall responsibility for the project, which involves a large number of contracts with individual contractors.

The latter two approaches require a strong domestic capability in project management. Even so, for a first NPP, an architect-engineer experienced with NPP projects should be retained. For a country with little experience with the management of large projects, the turnkey approach is recommended.

Recent contracting models for nuclear power projects are:

- The BOT approach: In a BOT approach (see for example Section 8.8.1 of [7] and Section 6.3 of [66]) a consortium of foreign investors establishes a joint venture company (JVC) with a local utility and the JVC sells the electricity (or any other energy product, e.g. heat) to the local utility. The JVC builds the power plant with foreign engineering expertise and operates the plant until all costs have been recovered by means of the electricity tariff, after which ownership of the plant is transferred to the country in which it has been built. During the period of operation by the JVC, domestic staff are trained so that when ownership is transferred there is a domestic management and operating team in place that can assume responsibility for the continued operation of the plant.
- The BOO approach: In this approach the ownership of the plant is retained by the JVC (see example of a BOO contract in Ref. [67]).

An important consideration in the BOO/BOT approaches is the question of providing the JVC with adequate assurances that it will be able to sell its product at an attractive price and so be able to recover its investment. The issues of investment risk and return on investment are discussed in the economics publication of the INPRO manual [11]. Another issue is limiting the liability of the JVC in the event of an accident. It would be expected that a JVC would be prepared to participate in a BOO/BOT project only in a State that has signed and ratified one of the international conventions dealing with nuclear liability (see Section 3.2.1).

The turnkey contract and especially the BOO/BOT approach can be used also as an option to reduce the necessary front end investment in national infrastructure, at least at the beginning of a nuclear power programme (see user requirement UR6).

INPRO has defined five criteria CR2.1–CR2.5 for user requirement UR2, set out in Table 4.

TABLE 4. CRITERIA OF USER REQUIREMENT UR2

| User requirement | Criteria | Indicators (IN) and acceptance limits (AL) |
|---|---|---|
| UR2 Industrial and economic infrastructure:<br><br>The industrial and economic infrastructure of a country with an NES should be adequate to support the project throughout the complete lifetime of the nuclear power programme, including planning, construction, operation, decommissioning and related waste management activities | CR2.1: Funding of infrastructure | IN2.1: Funding needed for the infrastructure of a nuclear power programme<br><br>AL2.1: Sufficiently available to cover the nuclear power programme |
| | CR2.2: Size of nuclear facility | IN2.2: Size of nuclear installation<br><br>AL2.2: Matches local needs |
| | CR2.3: Siting | IN2.3: Process of siting a nuclear facility<br><br>AL2.3: Siting process has taken safety, security and environmental requirements into account in accordance with international standards |
| | CR2.4: Support infrastructure | IN2.4: Availability of infrastructure to support owner/operator<br><br>AL2.4: Internally or externally available |
| | CR2.5: Added value | IN2.5: Added value of a nuclear power programme to society<br><br>AL2.5: Added value > infrastructure investment by the government necessary to support nuclear power programme |

### 3.3.3. Criterion CR2.1: Funding of infrastructure

*Indicator IN2.1:* Funding needed for the infrastructure of a nuclear power programme.
*Acceptance limit AL2.1:* Sufficiently available to cover the nuclear power programme.

The funding of the development and maintenance of a national infrastructure needed for an NES is the joint responsibility of the owner/operator, government and domestic industry.

It should be mentioned that the funding costs of nuclear infrastructure per MWe of nuclear capacity installed are significantly reduced if, after the first NPP, a series of plants with a comparable design is to be built in the country.

The financing of a nuclear power installation project and its operation is fully addressed in the economics publication of the INPRO manual [11] and is not considered further here. Therefore, this section considers only the funding of the corresponding national infrastructure.

INPRO has defined the following evaluation parameters (EP2.1.1 and EP1.1.2) of CR2.1 dealing with the funding of the investment by national industry and the State.

#### *3.3.3.1. Evaluation parameter EP2.1.1: Funding of support infrastructure provided by national industry*

The scope of support infrastructure to be established and maintained by national industry has been discussed above in Section 3.3.1.1. Sources of funding for industrial infrastructure include the financial resources of industrial companies themselves, domestic sources of financing including the government, and international sources. The availability of such funding on reasonable terms to national industry could be evaluated by means of a cost–benefit analysis of the planned investments. The analysis should show the feasibility of the funding and demonstrate a sound business case. However, it is unlikely that an INPRO assessor would obtain direct access to the economic planning results of national private industry involved in a nuclear power programme. Thus, it is deemed sufficient for the INPRO assessor to receive confirmation from the national industry involved that the necessary investments can be raised.

Acceptability of EP2.1.1 (condition for a positive judgement): Evidence is available to the INPRO assessor that the funding to build up and maintain the necessary national industrial support infrastructure can be raised by national industry.

*3.3.3.2. Evaluation parameter EP2.1.2: Funding of infrastructure provided by government*

Funding the establishment and operation of nuclear infrastructure lies within the responsibility of the government, i.e. regulatory bodies; upgraded means of transportation such as roads, bridges, ports or airports; institutions and installations for research and education are usually covered by the government's budget. The funding of the operation of such infrastructure could be raised partly via taxes on energy products sold by the utility, and fees received from the utility (e.g. for licensing).

The availability of government funds necessary for the investment may be verified through a corresponding evaluation of budget resources.

Acceptability of EP2.1.2 (condition for a positive judgement): Evidence is available to the INPRO assessor that the necessary State budget for funding nuclear infrastructure in the responsibility of the government is confirmed.

*3.3.3.3. Final assessment of criterion CR2.1: Funding of infrastructure*

The acceptance limit AL2.1 (Funding needed for the infrastructure of a nuclear power programme is sufficiently available to cover the infrastructure necessary for the programme) of CR2.1 is met only when the assessment of the two evaluation parameters provide a positive result.

### 3.3.4. Criterion CR2.2: Size of nuclear facility

*Indicator IN2.2:* Size of nuclear installation.
*Acceptance limit AL2.2:* Matches local needs.

This criterion deals with an element of infrastructure under the responsibility of the owner/operator of a nuclear facility. 'Installation' means each facility constituting the nuclear fuel cycle, including the NPPs. In case of a planned addition of an NPP, the 'local needs' are defined as the additional energy needed in the country or region based on the predicted growth of the national or regional demand for energy products by nuclear power. In the case of a replacement project, 'local needs' refers to the need for replacement of an existing plant.

*3.3.4.1. Size of NPPs*

The term size means here the electrical power output (capacity) or amount of energy produced by the planned nuclear plant (e.g. heat).

From a technical point of view, the optimum size of a nuclear plant producing electricity will firstly depend on the size of the grid to which the plant is to be connected. To ensure the stability of the existing grid, a useful rule of thumb is that the output of any single unit, in this case of the nuclear plant, should not be more than about 10 % of the peak load of the grid (see, for example, Ref. [65]). The mode of dispatch, i.e. the ranking of power plants in a grid, also influences the optimum size [68]. If the national grid is interconnected with neighbouring countries, of course bigger nuclear units could be installed.

As described earlier (Section 2.1), the influence of economic and technical considerations on the optimum size of an NPP to be installed is to be studied in an energy system expansion study during the planning phase of a nuclear power programme. The outcome of such a study could be the least cost pattern of system expansion to meet the power demand over a given period. The results of such planning studies can be found in Refs [69–72].

*3.3.4.2. Size of other facilities of the nuclear fuel cycle*

When considering other components of an NES, such as those at the front and back ends of the nuclear fuel cycle (e.g. a fuel fabrication plant and a waste disposal facility), the size of such facilities that would meet domestic needs has to be determined accordingly. Factors influencing the optimal size include the local and regional market situation, the planned development of the national nuclear power programme and the arrangements chosen for fuel supply and handling of spent fuel. This issue is also discussed in the economics publication [11] of the INPRO manual.

To emphasize the importance of such energy system planning and to ease the evaluation of CR2.2, the INPRO methodology defines two evaluation parameters (EP2.2.1 and EP2.2.2).

*3.3.4.3. Evaluation parameter EP2.2.1: Size of NPP*

As discussed above an (national) energy system expansion study should have been performed to determine the optimum size and schedule of deployment for the installation of one or several NPP(s). As noted in the overview manual of the INPRO methodology[30], such a study should have been completed prior to beginning an assessment providing an important input to the INPRO methodology assessment.

An important part of an energy system expansion study is the evaluation of grid stability including the planned installation of a new NPP (see, for example, Refs [65, 73–75]).

An NPP puts several requirements on the grid it is to be connected to, and vice versa:

— The electric grid should provide reliable off-site power to NPPs with a stable frequency and voltage.
— Any potential lack of reliability in off-site power from the grid must be compensated for by increased reliability of on-site power sources for the NPP.
— Enough reserve generating capacity should be available to ensure grid stability to replace NPP generation during planned NPP outages.
— The grid should also have a sufficient ‘spinning reserve’ and standby generation capacity that can be quickly brought on-line in case the NPP were to be disconnected unexpectedly from the grid.
— The off-peak electricity demand should preferably be large enough for the NPP to be operated in a baseload mode at constant full power.
— If there is any possibility of the NPP being operated in a load following mode, any additional design requirements to ensure safe load following operation should be discussed in advance with the NPP designer or vendor company.
— If baseload operation will not be possible, the NPP should have additional design margins to compensate for the increased exposure to thermal stress cycles and more sophisticated instrumentation and control systems.
— The national grid should have enough interconnections with neighbouring grids to enable the transfer of large amounts of electricity in case it is needed to offset unexpected imbalances of generation and demand.
— In preparation for the introduction of an NPP, if grid reliability and the frequency and voltage stability of the existing grid are insufficient, they should be made sufficient before the NPP is brought on-line. Any improvements will not only allow the grid to incorporate the new NPP but will have additional benefits for all customers and other generators.
— Communication is critical, in this case between the NPP operators and grid dispatchers. Effective communication protocols will need to be developed.

Acceptability of EP2.2.1 (condition for a positive judgement): Results of an energy system expansion study including an evaluation of the grid stability to confirm the acceptability of the chosen size and type of the planned NPP are available to the INPRO assessor.

*3.3.4.4. Evaluation parameter EP2.2.2: Size of nuclear fuel cycle facilities (other than NPPs)*

An analysis based mainly on economic, technical and strategic considerations (e.g. security of supply) should be performed to determine the size of nuclear fuel cycle facilities, taking as a basis the energy system expansion plan, local needs and the market situation at local and regional levels, and considering all available competitive options (e.g. external fuel supply) as well as potential limitations due to existing infrastructure (e.g. available

[30] A publication on this subject is in preparation.

funding). The pure economic aspect of installing domestic facilities of the nuclear fuel cycle, e.g. a fuel fabrication facility, is discussed in more detail in the economics publication of the INPRO manual [11].

Acceptability of EP2.2.2 (condition for a positive judgement): Evidence is available to the INPRO assessor that the size of nuclear facilities has been determined by means of adequate studies.

*3.3.4.5. Final assessment of criterion CR2.2: Size of nuclear facility*

The acceptance limit AL2.2 (size of nuclear installation matches local needs) of CR2.2 is met only when the assessment of the two evaluation parameters EP2.2.1 and EP2.2.2 provide a positive result.

Relevant departments of qualified multinational organizations such as the IAEA may provide support in assessing this INPRO methodology criterion.

### 3.3.5. Criterion CR2.3: Siting

*Indicator IN2.3:* Process of siting a nuclear facility.
*Acceptance limit AL2.3:* The siting process has taken safety, security and environmental requirements into account, in accordance with international standards.

The evaluation of the suitability of a site for the installation of a nuclear facility requires high expertise and the necessary studies should be performed in accordance with internationally agreed standards, especially regarding nuclear safety issues. In the following subsections, applicable standards for this topic are briefly presented.

The IAEA Safety Guide, Site Evaluation for Nuclear Installations [76], notes that “the site and the design for the nuclear installation shall be examined in conjunction to ensure that the radiological risk to the public and the environment associated with radioactive releases is acceptably low”. In some States, the environmental protection authority (or agency) is required to separately approve the siting of a nuclear facility from the environmental point of view.

According to Ref. [77], the following main factors may be used to determine appropriate sites for nuclear reactors:

— Health, safety and security factors;
— Engineering and cost factors;
— Socioeconomic factors;
— Environmental factors.

Health and safety factors are covered in the specific IAEA safety standards [78] and include issues such as the magnitude and frequency of natural external events (e.g. earthquake), human induced external events and site characteristics related to radiological impact.

Examples of engineering and cost factors are: suitability of water for cooling, suitability of existing electricity infrastructure, location of major load centres and selling price, suitability of transport infrastructure, and site development and construction costs.

Examples of socioeconomic factors are: future land use planning and sites ownership, regional economy and local society. An important aspect of local society is its acceptance of nuclear power because this influences the availability of a potential site.

Examples of environmental factors are: general ecosystem characteristics, aquatic ecology and marine impact, terrestrial ecology and freshwater impact.

*3.3.5.1. Final assessment of criterion CR2.3: Siting*

The acceptance limit AL2.3 (siting process has taken safety, security and environmental requirements into account) of CR2.3 is met if there is evidence available to the INPRO assessor that during the siting process all relevant requirements regarding safety, security and environmental protection have been taken into account in accordance with international standards.

### 3.3.6. Criterion CR2.4: Support infrastructure

*Indicator IN2.4:* Availability of infrastructure to support owner/operator.
*Acceptance limit AL2.4:* Internally or externally available.

The term 'support infrastructure' is understood here to be primarily the industrial infrastructure, especially the hardware such as facilities and equipment needed to support a nuclear power programme during its lifetime and to a lesser extent the infrastructure provided by the government in areas such as transportation. The corresponding human resources for research, education and training are treated in user requirement UR4. The owner/operator of nuclear facilities is not part of the support infrastructure itself, but needs goods and services provided by industry and government.

The term 'internally' means the domestic infrastructure within a country and 'externally' means support infrastructure provided by an institution in another country through regional or international arrangements.

As described above, the government is responsible for some of the hardware related support infrastructure, such as offices needed for regulatory activities, facilities for emergency response and means of transportation (ports, roads, bridges, etc.). The institution of the regulatory body was handled in user requirement UR1.

Industry is to provide equipment for transportation (e.g. trucks), construction, erection (e.g. cranes), maintenance and repair (e.g. spare parts) and for fabricating and manufacturing the necessary materials and components for nuclear installations (including the corresponding facilities and shops).

The criterion CR2.4 emphasizes the possibility that the industrial support infrastructure could be provided either by local (national), regional and/or international arrangements (to be discussed further in user requirement UR6). Clearly, the hardware to be provided by government remains a national task (e.g. infrastructure for transportation).

Two major steps are considered adequate to determine the appropriate industrial infrastructure at the national level:

- Perform a survey of capabilities (Section 5.8.3 of Ref. [17]) of national industry.
- Develop a plan or policy for the participation of national industry (chapter 4 of Ref. [62] [31]).
- Both the survey and development of the participation plan or policy should be a joint effort by the State, the owner/operator and industry.
- The plan or policy developed to determine the participation of national industry should address a variety of questions including the following (Section 1.3 of Ref. [68]):
  - Has the degree[32] to which the country wishes to be independent with respect to the execution of the programme and the operation and maintenance of the plants been determined?
  - Has the feasibility and extent of participation of present industries, utilizing their existing know-how, been determined?
  - Has the need for new technology and facilities been identified?
  - Is the plan for acquiring the needed know-how and facilities compatible with the timing of the nuclear programme?
  - Has the investment that is required to establish the planned industrial infrastructure been identified and is the investment[33] needed economically viable?
  - Will the new infrastructure provide opportunities for new non-nuclear work and will it help to make existing industries more competitive?
  - Will capable human resources[34] be available to meet the additional load implied by participation in the nuclear programme?
  - Is the nuclear programme based on firm decisions and unlikely to change along the way?

[31] INPRO recommends to use the support of international organizations with relevant experience (in the case of the IAEA, such support is provided via Technical Cooperation Projects) when drawing up a plan.

[32] This 'degree' will influence what kind of contract will be chosen for the supply of a nuclear facility and which regional or international arrangements for support services are taken into account.

[33] Funding of the investment is dealt with in CR2.1.

[34] Human resources are dealt within UR4.

It is obvious that the choice of contract[35] model for the supply of a nuclear facility (multiple packages, turnkey, BOO, BOT, etc.) will have a significant influence on this plan. On the other hand, in developing the plan, options offered at a regional and international level that could reduce investment in additional domestic capacity should be considered, e.g. by sharing support infrastructure with other countries (to be discussed further in UR6).

INPRO has established three evaluation parameters, EP2.4.1–EP2.4.3, for CR2.4.

*3.3.6.1. Evaluation parameter EP2.4.1: Survey of the existing capabilities of the national industry*

To be adequate, the survey should have been performed in the planning phase of the nuclear power programme and should have followed practices internationally recognized (e.g. section 5.8.3 of Ref. [17]).

Acceptability of EP2.4.1 (condition for a positive judgement): Evidence is available to the INPRO assessor that an adequate survey has been performed.

*3.3.6.2. Evaluation parameter EP2.4.2: Plan for the participation of national industry in nuclear power programme*

To be adequate, the plan should be based on the results of the survey on the existing national capabilities of the industry (EP2.4.1) and be performed following recognized procedures (see e.g. section 1.3 of Ref. [68]). Also, it should have evaluated the opportunities to optimize investments by using regional or international arrangements, i.e. external supply (discussed further in user requirement UR6). The timely evolution of the role of national industry (see Section 3.3.1) should be defined.

Acceptability of EP2.4.2 (condition for a positive judgement): Evidence is available to the INPRO assessor that an adequate plan for the participation of national industry in the nuclear power programme has been established jointly by government, the owner/operator and industry.

*3.3.6.3. Evaluation parameter EP2.4.3: Infrastructure provided by the government*

As discussed in Section 3.3.1, the government has a role in providing part of the support infrastructure necessary for a nuclear power programme. The main task is to assure that the transportation of heavy and bulky components of NPPs, e.g. the reactor pressure vessel, is possible via ports, roads, bridges, etc.

Acceptability of EP2.4.3 (condition for a positive judgement): Evidence is available to the INPRO assessor that transportation of heavy and bulky nuclear components is possible.

*3.3.6.4. Final assessment of criterion CR2.4: Support infrastructure*

The acceptance limit AL2.4 (infrastructure to support owner/operator is internally or externally available) of CR2.4 is met only when the assessment of the three evaluation parameters EP2.4.1–EP2.4.3 provides a positive result.

### 3.3.7. Criterion CR2.5: Added value

*Indicator IN2.5:* Added value of a nuclear power programme to society.
*Acceptance limit AL2.5:* Added value > infrastructure investment of the government necessary to support a nuclear power programme.

The term ‘added value’ is meant here to include the value of all possible spin-offs and benefits of the development of a nuclear power programme to society.

The term ‘investment necessary to support a nuclear power programme’ means the investment by the government in additional support infrastructure necessary to introduce and maintain the nuclear installations. As stated before, the capital investment in an NPP and related facilities, such as waste management facilities, fuel fabrication facilities, etc. is evaluated in the INPRO area of economics (see the economics publication of the INPRO manual [11]) and is not considered further here.

[35] See also types of contract in Section 3.3.2.

### *3.3.7.1. Spin-offs and benefits of a nuclear power programme*

Several valuable references (section 8.4.4 of Ref. [18]; section 10.1 of Ref. [7]; section 11.5 of [79]; and [80–82]) address the question of the spin-offs and benefits of a nuclear power programme to society, but mostly in a qualitative rather than a quantitative manner.

The benefits or spin-offs to society of introducing nuclear energy presented qualitatively in the literature include:

— Delivery of new products with higher quality by industry (see section 6.6. of Ref. [63]);
— Increased competitiveness of industry by increasing the technological capability of the country leading to more possibilities for export;
— Improvement of the overall economy by an increase of production;
— Additional higher skilled jobs in areas such planning, engineering, manufacturing and service;
— Improvement of national independence and security of energy supply;
— Avoidance of greenhouse gas emissions by utilizing nuclear energy;
— Conservation of fossil resources (oil, coal) needed for chemical industry;
— Avoidance of cost fluctuations of electricity or other energy products by utilizing nuclear energy for which variable costs (fuel and other) are a small fraction of the total cost;
— Production of isotopes used in medical applications [83].

The first four bullets are more related to national industry, whereas the other bullets describe benefits to society in general.

Spin-offs from nuclear research activities include innovations such as the development of new materials, new equipment (e.g. for non-destructive testing), creation of new companies and use of radiation sources for applications in medicine and agriculture [80–82].

Criterion CR2.5 requires that the benefits of a nuclear power programme to society listed above have to be compared to the investment by the government in national infrastructure.

A quantitative determination of the added value of a nuclear power programme to society is a complex task. Preferably, the government should perform a study comparing all benefits and possible spin-offs that (are expected to) result from their (planned) investments (Section 3.3.2) into additional support infrastructure under its responsibility, including any government investment required to support the industry.

At the time of writing, one detailed study was available that covers the impact of nuclear technology on the economic development of a country [63]. This study was performed by a number of national organizations involved in the development and operation of the national nuclear power programme during a period of five years with support from PESS. The study looked at the national and regional economic value added by installing nuclear power instead of alternative energy sources such as fossil power (coal or liquefied natural gas). The actual value added contribution of nuclear power to the GDP of the country in the year 2005 was estimated to be at least 1.3%. By comparison, the four major industries in the country, i.e. primary iron and steel products, semiconductors and related devices, motor vehicles and petroleum refinery products, contributed 1.3%, 2.1%, 2.2% and 2.9%, respectively, to GDP in the same year. The incremental value added, i.e. subtracting the potential contribution to GDP by alternative energy sources, is at a minimum around 0.4%. Thus, the nuclear power programme contributes in a significant way to the economic development of the country.

### *3.3.7.2. Final assessment of criterion CR2.5: Added value*

The acceptance limit AL2.5 (the value added to society by a nuclear power programme is greater than the infrastructure investment of the government, which is necessary to support the nuclear power programme) of CR2.5 is met when the results of a study that justify the investment required to support a nuclear power programme are available to the INPRO assessor. Owing to the significant effort needed to perform such a study, it is deemed sufficient for the INPRO assessor to compare the comprehensive study in Ref. [63] mentioned above to the situation in the country assessed and to conclude that similar positive effects are to be expected, i.e. no factors are found that contradict the results presented in Ref. [63].

## 3.4. USER REQUIREMENT UR3: POLITICAL SUPPORT AND PUBLIC ACCEPTANCE

*User requirement UR3:* Adequate measures should be taken to achieve and maintain public[36] acceptance of an NES being planned or in operation to enable a government policy commitment to support the deployment and operation of the system.

Energy remains a strategic commodity and ensuring its availability and the security of continuous and stable supply is one important aspect of governments' ultimate responsibility for national security and economic growth. Thus, planning and decision making for an energy system and electricity supply are important for governments. Because of its characteristics, adopting nuclear energy as a supply option requires a policy decision by governments. As has already been discussed extensively, to come to such a policy decision, governments must judge that the benefits of nuclear power outweigh the costs.

One of the potential costs (risks) of nuclear power is the potential for public opposition. Thus, an acceptable level of public acceptance is needed for a government to commit to the use of nuclear power as an energy supply option. Further, public acceptance needs to be sustained for a State to sustain its commitment.

This user requirement addresses actions to be taken by the government, the owner/operator and industry to gain and sustain public support for nuclear power. The role of the INPRO assessor is mainly to check whether the actions performed (or planned) are adequate and have been (or will be) successful.

### 3.4.1. Public acceptance

Although nuclear energy is a well-established component of electricity supply in many countries, the implementation of nuclear projects has raised social concerns that the associated risks cannot be adequately managed. Thus, for example, in some OECD countries, public acceptance of nuclear programmes has become a major issue.

The following discussion of public acceptance of nuclear power is primarily applicable to OECD countries [84], but at least some aspects of public acceptance are likely to be more broadly applicable.

Societal concerns need to be addressed by adequate measures, in particular by informing and consulting interested stakeholders and providing such stakeholders an opportunity to be involved in decision making processes [85]. The overall aim is to achieve broad agreement on key issues, recognizing that consensus will not be possible. Therefore, by defining user requirement UR3, INPRO methodology emphasizes the need to achieve a level of public acceptance within a country considering whether to start, maintain or enlarge a nuclear power programme, to enable a policy decision in favour of nuclear power. Without such support, energy policies and choices of supply mix can probably not be optimized. Support is needed at two levels — national and local. In this context, local is taken to mean the public that would be most affected by the nuclear facility, i.e. those in its vicinity. Even in the event of broad national support, local opposition may prevent nuclear projects from proceeding. The converse is also true.

Public acceptance issues of nuclear power vary from country to country and so there is no general 'one size fits all' approach for dealing with this issue. In some countries, public opposition has stopped the building of new NPPs and led, in some cases, to plans for the phasing out of operational NPPs, even in countries that were developers of NPPs. On the other hand, other countries are expanding or planning to expand their nuclear capacity and are maintaining extensive research, development and demonstration programmes. Despite these differences, there seems to be a number of common issues that are important to the question of public acceptance.

The installation and operation of an NES needs to address, to the extent possible, nuclear issues of general concern (section 9 of Ref. [7]). These include concerns about routine emissions of radioactivity and the potential for wide spread contamination, even beyond national borders, as a result of a serious reactor accident. Serious accidents in the past have influenced public opinion, not only in the country where the accident has occurred, but also globally. Other issues include the claim that there is no safe way to manage used (or spent) nuclear fuel and waste and the alleged close link between civilian nuclear power and nuclear weapons. INPRO methodology has developed basic principles, user requirements and criteria for NES that deal with the technical aspects of these issues. Thus, an NES that complies with all INPRO methodology requirements, using innovative or evolutionary designs, will address the issues that are of concern to the public acceptance head on. But technical improvements may not be sufficient without appropriate public communication and involvement.

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[36] 'Public' refers here to all stakeholders in a nuclear power programme, i.e. society.

*3.4.1.1. Risk and perception of risk*

The issues of public concern, introduced above, are related to the issue of risk perception. Therefore, the concepts of risk and of risk perception by individuals and the public are discussed in more detail, below. This discussion is based on information presented in the OECD/NEA report Society and Nuclear Energy (chapter 3 of Ref. [84]).

The scientific definition of risk is the probability of occurrence of an event multiplied by the associated hazards or consequences:

$$Risk = Probability \times Hazard$$

This mathematical formula is widely accepted by experts and scientists; however, the public perception of risks is not captured by such a formulation. Further, while the methodology of probabilistic risk assessment or probabilistic safety assessment is commonly used by experts to quantify risk, this approach is, unfortunately, incomprehensible to a non-expert. Thus, it can be argued scientifically that the risk of getting cancer from a radiation exposure of 1 mSv/a is about the same as that from smoking three packets of cigarettes a year. But the public seem more concerned about exposing themselves to radiation than to cigarette smoke, although by radiation they mean that resulting from routine emissions from nuclear facilities, even though exposure to natural radiation is inevitable and the annual dose from natural radiation is many times greater than that from routine emissions.

For a non-expert, risk would appear to represent 'a threat to people or things to which they have an emotional attachment'. The following have been identified as important factors that affect the perception and acceptance of a risk by an individual [84]:

- Trust in the institutions controlling nuclear safety and security: The risk will be more readily accepted if the public trusts the regulatory bodies and the owner/operator.
- Whether a risk is imposed or accepted voluntarily: Imposition of a decision on individuals that are potentially affected or removing individual or local control are huge multipliers of perceived risk. The amplification of risk perception could be so high that it prevents real communication about risks and the off-setting benefits of a project.
- Degree of control: People are more concerned about risks not under their personal control (nuclear energy or flying in a plane) than about risks under personal control (driving cars or smoking cigarettes).
- Benefit/reward: The acceptance of risk by an individual or group is increased if there is an associated benefit to the individual or group. Smoking is a good example for compensation or reduction of perceived risk by a reward.
- Understanding: A risk is perceived to be more significant if it is not well understood or familiar. Experience has shown that knowledge and, more generally, the education level of the public strongly influences the perception of risk.
- Catastrophic potential: Accidents that cause fatalities grouped in time and space are perceived as having a much higher risk compared to accidents with scattered or random deaths. Examples are an aeroplane crashes vs. automobile accidents.

Based on the above, it can be appreciated that when considering risks and benefits there is need to provide relevant and understandable information to society and to provide an opportunity for public participation in decision making. The processes used for public communication and participation would be expected to differ from one country to another. But, in all cases it would be expected that governments, the owner/operator and industry would participate.

*3.4.1.2. Information to society*

A public information programme, aimed at both the general public and the local population around the (potential) site of a nuclear installation, should be carefully planned and implemented by the government, the owner/operator and industry. Communication should start as early as possible, to increase the understanding of nuclear issues within society, thereby providing a basis for an informed discussion. Communication by the nuclear regulatory bodies is also important. They need to inform the public and other interested parties and the media about the safety aspects of facilities and about regulatory processes. These issues are discussed further when considering criterion CR3.1 (public information).

*3.4.1.3. Participation in decision process*

Participation by interested individuals and groups in the decision making process increases trust and the sense of control of the process, and so should improve communications about risks and benefits and the level of knowledge about a nuclear power programme. This concept is discussed further when considering criterion CR3.2 (public participation).

*3.4.1.4. Survey of public opinion*

The evaluation of broader public opinion concerning important aspects of nuclear energy can be determined on a statistical basis using public opinion surveys, supplemented with focus group discussions. Such information would supplement that obtained from communications with individuals and groups that are actively participating in decision making processes. An illustrative example of public polling, including a discussion of measurement techniques, is provided in Ref. [86]. Examples of results of public surveys performed in OECD countries can be found in chapter 6 of Ref. [84].

For user requirement UR3, INPRO methodology has defined five criteria, CR3.1 to CR3.5, as shown in Table 5.

TABLE 5. CRITERIA OF USER REQUIREMENT UR3

| User requirement | Criteria | Indicators (IN) and acceptance limits (AL) |
|---|---|---|
| UR3: Political support and public acceptance:<br><br>Adequate measures should be taken to achieve and maintain public acceptance of an NES being planned or in operation to enable a government policy commitment to support the deployment and operation of the system | CR3.1: Public information | IN3.1: Information on nuclear power programme provided to public<br>AL3.1: Sufficient according to national requirements, taking into account international practice |
| | CR3.2: Public participation | IN3.2: Participation of public in decision making process on a nuclear power programme<br>AL3.2: Sufficient according to national requirements, taking into account international practice |
| | CR3.3: Survey of public acceptance | IN3.3: Public acceptance of nuclear power<br>AL3.3: Sufficient to expect that the political risk of policy support for nuclear power is acceptable |
| | CR3.4: Policy support | IN3.4: Government policy regarding nuclear power<br>AL3.4: Policy is supportive of nuclear power |
| | CR3.5: Political, environment and investor risk[37] | IN3.5: Long term political commitment to a nuclear power programme<br>AL3.5: Commitment sufficient to enable a return of investment |

[37] In comparison to TECDOC-1575/Rev.1 [1], this criterion was added.

### 3.4.2. Criterion CR3.1: Public information

*Indicator IN3.1:* Information on nuclear power programme provided to public.
*Acceptance limit AL3.1:* Sufficient according to national requirements, taking into account international practice.

Several aspects are important regarding the provisions of information on nuclear issues:

— Information about a nuclear power programme should always be explained to the public within the context of objectives for the social, political and economic development of a country and within the context of national energy demand and all energy supply options.
— The information should describe the benefits of a nuclear power programme and the associated risks in an objective manner. Adequate information on benefits and risks will increase the level of understanding among the public and consequently reduce the level of perceived risk.
— All areas of concerns need to be addressed, including waste management, safety, economics, proliferation resistance, environmental impacts, infrastructure — in short, the INPRO methodology areas. Performing and/or reviewing the results of an assessment of the nuclear power programme using the INPRO methodology may be helpful in such communications.

Different approaches can be used to communicate information to society, such as public meetings, hearings, web sites, advertisements in the media, distributions of booklets, information centres, etc. The information given needs to be referable, technically sound, accurate, reliable and understandable by the public [64].

Within society, several target groups (both on a local and a national level) who will receive information have to be distinguished, e.g. employees, media, local and national government officials, local and national opinion leaders, members of various groups such as medical groups, educators, students, labour unions, investors, consumer protection groups and the general public.

The form and content of the information may vary but the information must be consistent, accurate and complete to avoid the possibility that information gaps are filled by rumours and speculation. Opportunities also need to be provided for obtaining feedback — communication is a two-way process.

When discussing benefits and risks, the benefits and the risks need to be considered from both a national and a local perspective. In some situations, nuclear energy projects may be seen to provide a benefit to national industry and utility shareholders, while the associated risks are borne by the public and especially the local population in the vicinity of a nuclear facility. Thus, the benefits of a nuclear power programme to society and the public at large and to those living in the vicinity of the facility need to be clearly articulated, as well as the attendant risks.

The nuclear regulatory authorities[38] have a special and important role in providing information to the public [87]. They need to communicate safety issues to different audiences, such as decision makers (government, politicians), the public (in general, and especially to people living close to a nuclear facility), NGOs and news media. The main goal of their information strategy is to inform the public how they ensure safety and security, non-proliferation and environmental protection in all nuclear installations, thereby laying the foundation of public trust. An important aspect to be mentioned is that nuclear regulatory authorities inform society about certain aspects of a nuclear power programme, but leave the benefits of such a programme to be communicated by other organizations within the government (e.g. ministry of energy), by the operator and by the industry involved.

INPRO methodology has specified several evaluation parameters, EP3.1.1 to EP3.1.4, for criterion CR3.1; these are discussed below.

#### *3.4.2.1. Evaluation parameter EP3.1.1: Communication of benefits of nuclear power to the public*

As discussed at the beginning of Section 3.4, the acceptance of a perceived risk is increased if the benefits to those exposed to the risk are known. Thus, it is important that the benefits of adopting nuclear power are clearly articulated. In the discussion of criterion CR2.5 (added value), some of the benefits of a nuclear power programme were discussed. However, it is necessary to communicate these benefits and spin-offs of a nuclear power programme (whether they are associated with the first installation, replacement or enlargement of a nuclear

[38] For the function of the regulatory body, see CR1.2.

facility) in an appropriate way. Broadly speaking, the benefits need to be clear to two different audiences — the national audience, and the public and interested parties in the vicinity of the proposed plant. The benefits set out when discussing criterion CR2.5 largely represent national benefits. Local benefits include new opportunities for employment both in the construction phase and, in particular, long lasting jobs in the operating phase. Other benefits may include improvements in local infrastructure and an increased tax base for local governments (see also Ref. [63]).

The prime responsibility for communicating benefits to a local audience should belong to the owner/operator of the nuclear facilities and local industry. These groups also need to communicate national benefits, as does the government. In this connection, it needs to be noted that the communication of benefits of nuclear power should not be performed by regulatory bodies. Their focus is on nuclear safety and security. Therefore, a government department that is not responsible for regulations needs to take the lead in communicating national benefits.

To verify whether the relevant benefits and spin-offs have been clearly communicated, public survey techniques, including polling and discussions with focus groups, can be used. The results of such public surveys should be available to the INPRO assessor.

Acceptability of EP3.1.1 (condition for a positive judgement): Results of surveys available to the INPRO assessor show that the benefits of nuclear energy have been understood by the public.

*3.4.2.2. Evaluation parameter EP3.1.2: Information on the operation of nuclear facilities*

Experience has shown that owners/operators of nuclear facilities should provide information on their operations to the public on a regular basis, including information on incidents and accidents, to maintain public trust and foster acceptance of nuclear power. The information to be provided includes, but is not restricted to, the following: results of environmental monitoring, and in particular levels of radiation exposures and concentrations of radioactive materials; plans for and results of operational peer reviews and regulatory audits; processes used for the quality management of nuclear facilities, including the use of inspections; plans for outages and upgrades, etc. In some circumstances, the local public may identify specific issues of interest to them. In this connection, local politicians need to be briefed on a regular basis and be advised of planned changes and unusual events, since members of the public often consult with their representatives when concerned about something.

Not only operators, but also regulators have to communicate with the public on a regular basis. Some examples of information policy by owners/ operators of NPP [88] are found in Refs [89–91].

The success of such communication programmes can be confirmed by public surveys formulated to determine the effectiveness of communications. The INPRO assessor should have access to the results of such a survey performed by the operator.

Acceptability of EP3.1.2 (condition for a positive judgement): Evidence is available to the INPRO assessor that a policy on public communication is in place and the effectiveness of communications has been demonstrated, e.g. by surveys.

*3.4.2.3. Evaluation parameter EP3.1.3: Addressing concerns raised by the public regarding nuclear installations*

As previously stated, information provided to the public should discuss not only benefits but also the risks associated with nuclear installations and the means of controlling these risks. As noted in both editions of the IAEA Handbook of Nuclear Law [14, 15], an activity that involves only hazards and no benefits calls for prohibition, not regulation. Thus, a basic feature of nuclear activities and their regulation is the balancing of risk and benefits.

As stated in the IAEA report entitled Stakeholder Involvement Throughout the Lifecycle of Nuclear Facilities [85], the IAEA Guidebook on the Introduction of Nuclear Power (section 5.13 of Ref. [17]) and in an IAEA booklet [92], information on nuclear risks and their control should utilize comparisons with other risks that are familiar to the public and are generally accepted by society, including risks posed by other energy systems, taking into account the risks of the complete fuel cycle. Data on risks should be disaggregated as much as possible (e.g. early fatalities, fatal diseases, long term effects, etc.) and the uncertainties of the data should be identified. It may be noted that a fundamental requirement of nuclear safety and radiation protection is that an activity should only be undertaken if the benefits of the activity outweigh the related risks. The issue of the cost effectiveness of risk reduction should be also presented, including a discussion of whether or not money should be allocated to areas where the greatest risk reduction can be achieved per unit of safety expenditures.

The IAEA has published a practical handbook on communications on nuclear, radiation, transport and waste safety [84]. It is primarily intended to support nuclear authorities in their information programmes, but it could also be useful to operators and industry. Reference [84] describes in detail what kind of questions people may have, and how to answer them, in relation to a planned installation of an NPP, including facilities at the front and back ends of the fuel cycle. Additionally, the safety issues of ionizing radiation in medicine, industry, agriculture and research, the transport of radioactive materials, the management of radioactive waste and emergency preparedness and response are evaluated. Further, a process for establishing a communication programme to provide the necessary information to the public in an efficient way is outlined.

The INPRO assessor evaluating EP3.1.3 should check whether the existing communication programme appropriately addresses all significant concerns raised by the public regarding the safety and security of nuclear facilities and materials, and hence whether or not the risks involved have been adequately addressed. The IAEA practical handbook on communications [84] can be used as a benchmark in such an exercise. The success of this part of a communication programme can also be confirmed by means of surveys, as described in Ref. [86].

In this context, it is to be mentioned that the public in the European Union has a right to receive environmental information and take part in environmental decision making, based on the Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus Convention) [93].

Acceptability of EP3.1.3 (condition for a positive judgement): Evidence is available to the INPRO assessor that the communication programme adequately addresses issues of risk and benefits of a nuclear power programme.

*3.4.2.4. Evaluation parameter EP3.1.4: Use of communication experts to match information to the needs of public audiences*

It is highly recommended that communication experts should be used in planning communication programmes. Such experts, trained in nuclear issues, should also participate in the communication process. Having said that, experience in many countries is that the public also wants to interact with those responsible for planning and operating the plant, e.g. managers, scientists, engineers, technicians and tradespeople. With such a diverse group of communicators, it is important that everyone understands the key messages. The public also wants to communicate with the regulator. The focus of communications by the regulator should be on safety and security and the regulatory processes used by the regulator to ensure nuclear safety and security.

The expertise of communication specialists is needed when considering the style, content and form of information to be provided to different audiences. Good examples of matching information to the intended audience can be found in Refs [64, 87, 94].

Acceptability of EP3.1.4 (condition for a positive judgement): Evidence is available to the INPRO assessor that communication experts are participating in formulating and executing communication plans.

*3.4.2.5. Final assessment of CR3.1: Public information*

The acceptance limit AL3.1 (information to the public is sufficient according to national requirements, taking into account international practice) is met when the evaluation of all EPs defined above has been assessed positively.

Assistance to assessors may be provided, if necessary, by specialized international organizations such as the IAEA.

### 3.4.3. Criterion CR3.2: Public participation

*Indicator IN3.2:* Participation of the public in the decision making process on a nuclear power programme.
*Acceptance limit AL3.2:* Sufficient according to national requirements, taking into account international practice.

Historically (see for example section 9.2 of Ref. [7]), governments and legislative assemblies/parliaments have been the guardians of public safety and, with development, they have taken the decisions needed to secure the benefits from industrial activities that also pose hazards, including electrical power plants. When siting such facilities, local consultation processes have been developed in many countries to assist with the decision making process, for example by identifying local concerns and means to ameliorate them. In some countries (e.g. France, Hungary and Sweden), legal requirements for local consultations in regard to a planned nuclear power programme have been established. Experience has shown that, although very important, providing information only may not be sufficient to achieve the trust of the people affected by a nuclear power programme. People want to be listened to and be involved in the decision making process. They want their concerns to be recognized and taken into account.

In an OECD/NEA report on society and nuclear energy (chapter 4 of Ref. [84]) a public participation ladder is presented (Fig. 1). The level of public participation would be expected to vary from country to country, depending on its political processes, cultures, and traditions.

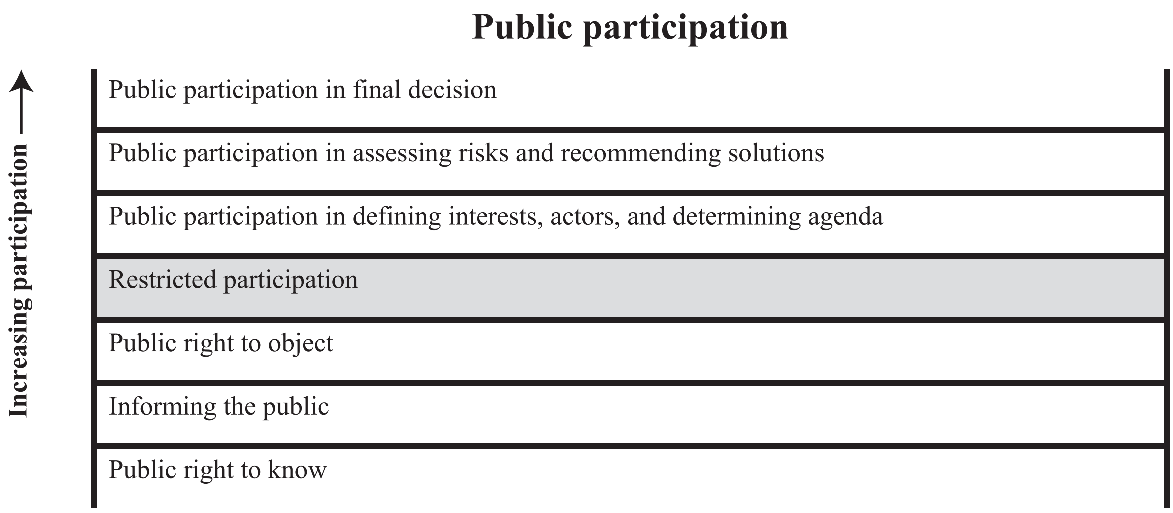


*FIG. 1. Public participation ladder.*

There are many approaches to how the public can be involved in the decision making process. These include the organization of consensus building meetings, peer dialogues, multi-stakeholder workshops, citizen juries, issue forums, consensus conferences and standing panels. The survey method uses questionnaires that may be administered by post, telephone or face to face. The internet is becoming a widely used tool for public participation. Several institutions, mainly regulatory authorities, are using internet web sites to communicate either non-interactively or interactively. Such an on-line system should [84]:

— Allow the public to explore and experiment with the presented data enabling the formulation of different scenarios and solutions to decision problems;
— Be understandable (avoiding technical jargon) by everybody in the local community who wishes to be involved;
— Provide information and data that is both explicit and representative of different viewpoints;
— Foster a high degree of trust that can be maintained.

While evaluation parameters and acceptance limits have been identified below, it is to be noted [30] that no single method can attain a perfect score. For instance, methods that score high on representation, such as opinion polls, standing panels and multiple focus groups, tend to score lower on process criteria, excepting cost effectiveness. So, in a given public participation process, several methods will need to be employed, each with a specific purpose in mind.

To verify the adequacy of public participation, INPRO methodology has followed the guidance provided in chapter 4 of Ref. [84] and specified two evaluation parameters (EP3.2.1 and EP3.2.2) for criterion CR3.2. The first one is related to the participation process, while the second is related to the potential for public acceptance of such a process.

### *3.4.3.1. Evaluation parameter EP3.2.1: Appropriateness of participation process*

There are four issues covered in evaluation parameter EP3.2.1 formulated as questions: (1) Accessibility of resources: Do the public participants have access to the appropriate information resources to enable them to successfully participate?

The necessary resources will depend on the way the participation is performed in an individual country. If, for instance, the form of meetings within a public participation programme is chosen, resources should be available so that stakeholders who wish to do so can travel to such meetings on nuclear issues; otherwise the meetings should be repeated in several places. If the participation programme uses web sites, stakeholders should also have access.

(2) Task definition: Has the nature and scope of the task in which the public is being asked to participate been clearly described? (3) Structured decision making process: To implement a successful participation exercise, has an appropriate mechanism for structuring the decision making process been established, and its outcome displayed and made clear to the participants?

An example of an effective structure is the establishment in the United Kingdom of a standing panel (chapter 4 of Ref. [84]) with 5000 participants, called the People's Panel. Another example is a so-called consensus conference. In such a conference, called for discussion of a specific topic, ordinary people with no specific background discuss with experts, and formulate, at the end, a consensus paper reflecting the agreed outcome of the conference.

(4) Cost effectiveness: Has the investment in a public participation programme been cost effective?

Acceptability of EP3.2.1 (condition for a positive judgement)**:** Evidence is available to the INPRO assessor that the 4 questions defined above have been answered positively.

### *3.4.3.2. Evaluation parameter EP3.2.2: Acceptability of participation process*

There are also four issues dealt with in evaluation parameter EP3.2.2, which are formulated as questions: (1) Representative sample: Has a broadly representative sample of the population of the affected public been involved to achieve a successful participation programme?

It is difficult to define quantitatively the term representative sample. Clearly, the public living close to a proposed nuclear site should be encouraged to be involved. But interested groups at the national level will also wish to participate. Care must be taken to structure the consultation process so that it is inclusive and so that special interest groups do not dominate the process. A recent example of a lengthy public participation process is that followed by the Canadian Nuclear Waste Management Organization in preparing a recommendation to the Government of Canada on an approach for the long term management of Canada's spent nuclear fuel (see chapter 3 of Ref. [95]).

In 1982, the General Assembly of the United Nations proclaimed the World Charter for Nature [96] which recognizes the need to inform the public, and the rights of individuals to participate in decisions concerning the environment. This charter has been used by some global environmental protection organizations to argue that they have a legitimate right to participate in national decision making. Regardless of the merits of such participation, on occasion such organizations have dominated local consultation processes, effectively reducing the voice of local participants. (2) Independence of the participation process: Has the participation process been conducted in an independent and unbiased manner? (3) Early involvement: Have the public been involved as early as possible?

The participation programme should provide enough time for involvement and be integrated in the overall process of planning the nuclear power programme, thereby avoiding unnecessary delays within the programme. On the other hand, governments, industry and the owner/operator need to be in a position to address issues and provide answers before engaging the public.

(4) Influence of results on policy: Has the public participation programme resulted in a visible impact on policy in order to achieve public trust?

Acceptability of EP3.2.2 (condition for a positive judgement): Evidence is available to the INPRO assessor that the 4 questions defined above have been answered positively.

### *3.4.3.3. Final assessment of CR3.2: Public participation*

The acceptance limit AL3.2 (public participation in the decision making process on a nuclear power programme is sufficient to foster public acceptance according to national requirements) of CR3.2 is met when evidence is available to the INPRO assessor that an overall evaluation of the public participation processes has been performed with positive results, using the EPs for guidance. The evidence might be the results of public surveys or polling, as discussed in the next criterion, CR3.4.

### 3.4.4. Criterion CR3.3: Survey of public acceptance

*Indicator IN3.3:* Public acceptance of nuclear power.
*Acceptance limit AL3.3:* Sufficient to expect that the political risk of policy support for nuclear power is acceptable.

The term 'political risk to policy support' reflects the possibility that political support for a nuclear power programme may fail owing to lack of public support leading either to a decision not to start a nuclear power programme or to a decision to phase out a programme that is already in place. Here, it may be noted that political leaders and governments can follow policies that are opposed by a significant percentage of their constituents as long as the majority of the population are either supportive of the policy or at least neutral (not opposed). Even if a majority of the population oppose a policy, governments may continue their support for a past position, at least for a time, in the hope that the opinion of the population will change. But, in the face of sustained and wide spread opposition, governments are unlikely to be able to sustain an unpopular policy position in the long term.

The main means of achieving public acceptance have been set out when discussing criteria CR3.1 and CR3.2. Thus, if the acceptance limits for criteria CR3.1 and CR3.2 have been met for a given country, criterion CR3.3 should be fulfilled automatically. But public opinion may change with time. Therefore, there is an ongoing need to gauge public acceptance of nuclear power. This is normally performed using public polling.

INPRO has defined the following three evaluation parameters, EP3.3.1–EP3.3.3, for criterion CR3.3.

#### *3.4.4.1. Evaluation parameter EP3.3.1: Surveys to gauge public acceptance are performed on a regular basis*

'Regular basis' means at an appropriate time interval, which depends on the situation of each country, taking into account the general political climate and factors that might affect public attitudes, such as adverse publicity concerning nuclear power programmes in other countries, heightened concerns about the proliferation of nuclear weapons, local opposition to the siting of a nuclear facility, etc.

In a situation where a nuclear programme has already been established, surveys to gauge public acceptance should be repeated at appropriate time intervals, e.g. about once a year. It may be noted that nuclear considerations are often not a topic of concern to the general public, in the absence of an event or action that raises an issue. One such event would be planning for a new nuclear project, such as a first NPP or a new fuel cycle facility. In these circumstances, surveys should be started early in the planning process, as one input to project risk management, and be continued on a relatively frequent basis until the facility has been operating for some time; then — as stated above — the interval for surveys may be adjusted to about once a year.

Acceptability of EP3.3.1 (condition for a positive judgement): Evidence is available to the INPRO assessor that public polling is performed on a regular basis, commensurate with circumstances.

#### *3.4.4.2. Evaluation parameter EP3.3.2: Adequacy of survey*

The surveys may be considered adequate when they are carried out by professional organizations using recognized practices and techniques (see, for example, Ref. [86]).

Acceptability of EP3.3.2 (condition for a positive judgement): Evidence is available to the INPRO assessor that surveys have been performed by certified professionals.

#### *3.4.4.3. Evaluation parameter EP3.3.3: Acceptable result of survey*

The results of a survey should show that a majority of the public either supports or at least does not oppose, a planned (or established) nuclear power programme and that there is a positive (or at least stable) trend.

Acceptability of EP3.3.3 (condition for a positive judgement): Evidence is available to the INPRO assessor that survey results indicate that a majority of the public supports the nuclear power programme with a stable or positive trend.

#### *3.4.4.4. Final assessment of CR3.3: Public acceptance*

The acceptance limit AL3.3 (public acceptance of nuclear power is sufficient to expect that the political risk of policy support for nuclear power is acceptable) of CR3.3 is met if the evaluation of the three EPs discussed above has a positive result, i.e. public attitudes are continuously monitored and public support is favourable (or neutral) and not strongly opposed towards the introduction and continued use of nuclear power.

### 3.4.5. Criterion CR3.4: Policy support

*Indicator IN3.4:* Government policy regarding nuclear power.
*Acceptance limit AL3.4:* Policy is supportive of nuclear power.

The availability of affordable energy underpins modern economies and so ensuring a sustainable supply of energy is a major responsibility of government. Nuclear power represents one potential source of sustainable energy. However, one of the characteristics of nuclear power is the long life cycle of an NPP project that extends from planning to siting, designing, constructing, operating and decommissioning, and which includes the safe management of the associated radioactive waste. The life cycle would be expected to extend well over fifty years in most cases and may extend beyond one hundred years.

Therefore, the existence of a national energy policy issued by government that sets out, inter alia, the potential role of nuclear power is important for an existing nuclear power programme and a prerequisite for a new programme. The envisaged role of nuclear power should be based on the results of appropriate (continuously updated) planning activities (e.g. an energy system expansion plan and a plan for the participation of national industry in the nuclear power programme) as described earlier in user requirement UR2.

The policy should be understandable by the general public and not only by experts. It should outline the national need for energy, the anticipated growth of energy demand and the practical options for meeting this demand. For a country that has not yet made a commitment to a nuclear power programme, it should explain why nuclear power is being considered as an option and explain the process by which the government will come to a decision on whether or not to commit to nuclear power and how interested parties can provide input to the decision making. For a country that already has nuclear power, the role of nuclear power in meeting current demand should be explained and the rationale for having adopted nuclear power should be set out, including the process that was followed in making a government commitment to this option. Good examples of such national policies are given in Refs [67, 97, 98].

In countries where the energy market is fully liberalized, the role of government in national energy planning may be diminished. Thus, the role of the owner/operator of existing and planned nuclear plants will be more important in the planning process. Nonetheless, the government will need to explain why it has approved past nuclear projects (if any) and the process to be followed in approving future projects, including the public consultation processes to be used.

Summing up, national energy policy is considered adequate if it clearly defines the role of nuclear power, and if the policy statement therein is comparable to the examples mentioned above (or to other similar ones), taking into account the specific situation or boundary conditions in the country.

#### *3.4.5.1. Final assessment of CR3.4: Policy support*

The acceptance limit AL3.4 (government policy is supportive of nuclear power) of CR3.4 is met if evidence is available to the INPRO assessor that the government has made a clear policy decision to support nuclear power in the long term.

### 3.4.6. Criterion CR3.5: Political environment and investor risk

*Indicator IN3.5:* Long term political commitment to a nuclear option.
*Acceptance limit AL3.5:* Commitment sufficient to enable a return on investment.

In the INPRO methodology area of economics (section 4.4.4. of Ref. [11]), political environment was identified as one economic criterion for assessing investor risk. It was further noted that the evaluation of this economic criterion is addressed in this publication of the INPRO manual.

Meeting the four infrastructure criteria, CR3.1–CR3.4 of UR3, should in principle be considered sufficient for meeting CR3.5.

However, a potential investor in a nuclear power programme (or the INPRO assessor) may also wish to consider other factors such as the following:

(1) Does the leading opposition party support nuclear power?
(2) Is there a political party that is actively opposing nuclear power and that could be expected to gain power?
(3) Has progress been made in addressing controversial issues, such as the siting of end state waste management facilities?
(4) Is there a system for resolving public concerns prior to committing significant project funds?
(5) Is the legal system such that interveners can unduly delay projects once a constructions permit has been issued?
(6) Has a new and credible alternative to nuclear energy, without major shortcomings, been identified/developed?

*3.4.6.1. Final assessment of CR3.5: Political environment and investor risk*

The acceptance limit AL3.5 (long term political commitment to a nuclear option is sufficient to enable a return on investment) of CR3.5 is met if evidence is available to the INPRO assessor that the 6 questions above could be answered in a positive way, i.e. questions 1, 3, and 4 with ‘yes’, and question 2, 5, and 6 with ‘no’.

## 3.5. USER REQUIREMENT UR4: HUMAN RESOURCES

*User requirement UR4:* The necessary human resources should be available to enable all responsible parties involved in a nuclear power programme to achieve a safe, secure and economical operation of the NES throughout its lifetime.

Qualified human resources are essential for the safety, security and reliability of nuclear power. This user requirement is to be fulfilled by the owner/operators of nuclear facilities, government, and, in particular, regulatory authorities, and by nuclear industry, i.e. all nuclear institutions in a country need skilled and trained personnel for successfully implementing, maintaining or enlarging such a programme. Governmental support is required for consistent long range policies on human resources development.

The role of the INPRO assessor is to check whether the needed human resources are (or will be) available (in time).

### 3.5.1. Human resources

*3.5.1.1. Human resources for establishing a nuclear power programme*

The IAEA report, Workforce Planning for New Nuclear Power Programmes [99] and the IAEA Guidebook for Manpower Development for Nuclear Power [100] lay out in detail the various considerations related to the provision of human resources for all phases of a nuclear power programme.

The government needs qualified personnel [12] for planning the nuclear power programme. The planning should involve, at the appropriate stage, the owner/operator and representatives of industry. As planning proceeds, the government will need to initiate public communications and as support for proceeding with a nuclear programme grows, presumably towards the end of the planning phase, the government will need to establish the legal framework (see UR1) and the regulatory bodies. The latter will need a competent management team and access to highly qualified staff. As construction of an NPP or other facilities of the fuel cycle progresses, the government has to establish an emergency preparedness plan, ensure that trained staff are available and put into place any emergency preparedness facilities needed. Additionally, the government will need to ensure that it has an adequate security force to meet the requirements for nuclear security. Depending on the plan for national participation in the nuclear power programme, the government has to ensure that facilities for education and training (e.g. science and technology institutions, research facilities) are established or upgraded, as the case may be.

The owner/operator of a nuclear facility will also be involved in the planning (section 7.6 of Ref. [62]) of a nuclear project. Depending on the type of contract chosen, the owner/operator may need considerable human resources during the construction phase, for example, for project management, quality management, commissioning, etc.

When embarking on a nuclear power programme, generally, a two step approach should be followed to put in place the necessary human resources.

The first step is to define the needs for human resources. The needs will depend on many factors, but primarily on the scope and schedule of the planned nuclear power programme, on the planned national participation, on the type of contract(s) for supply, and on national labour market conditions (e.g. productivity, efficiency, and labour rules and regulations).

Based on the results of the first step, in a second step a national plan for the development of human resources can be developed. This plan would also specify facilities that are needed for education and training and which need to be established or upgraded.

Experience has shown that the establishment of a nuclear research centre (see, for example, section 5.8.1.5 of Ref. [17]) with a research reactor can be a good start for a nuclear power programme and a valuable long term source of human resources for a (planned or operating) NES in areas such as reactor engineering, operations, safety and radiation protection, nuclear training, waste treatment and others. As mentioned in Section 3.3.7 of this publication (Criterion CR.3.5: Added value), examples of spin-offs from nuclear research activities, which could justify investment in R&D facilities, are the development of new materials, new testing equipment, and training in the use of radiation sources in medicine and agriculture.

*3.5.1.2. Human resources for an operating NES*

In a recent IAEA publication, Evaluation of Human Resource Needs for a New Nuclear Power Plant [101], the number of staff needed to operate a new WWER-1000 plant was estimated to be 450 at the plant site plus 50 in administration (Table 6).

TABLE 6. ESTIMATED NECESSARY STAFF TO OPERATE AN NPP (WWER-1000)

| Power unit | |
|---|---|
| Management and subsections | 50 |
| Operating personnel for NPP process management (non-production-shop-based) | 20 |
| Production subsections: | |
| — operating staff | 220 |
| — maintenance staff | 120 |
| Ancillary subsections | 40 |
| Total staff (for power unit) | 450 |
| **Operating organization** | |
| Top management | 10 |
| Management personnel | 15 |
| Operating organization subsections | 25 |
| Total staff (for operating organization) | 50 |

A 2011 IAEA survey of 67 operating NPPs in Europe and the US [99] has demonstrated a substantial variability in the numbers of total staff employed in operating NPPs. Mean values of total staff needed for the operation of a single power unit and for two units operated together were found to be 732 and 1012, respectively.

The IAEA has issued guidance on managing human resources in the field of nuclear energy [102], i.e. how to ensure an adequate staff during the lifetime of an NPP. The guidance provided in this publication is intended to comprehensively address various aspects such as ensuring that individuals have the competence needed to perform their assigned tasks, organizing work effectively, anticipating human resource needs, and monitoring and continually improving performance. To train the personnel involved in the operation of an NPP, an internationally acknowledged approach called SAT [103] (job specific systematic approach to training) is available.

For the decommissioning of a large NPP, the USNRC has estimated (see Section 2.4 of Ref. [104]) that a single unit NPP undergoing early dismantling needs a workforce in the range of 100–200 persons.

#### *3.5.1.3. Human resources for staffing the nuclear regulatory body*

The appropriate size for a regulatory body will depend on a range of factors: the various types and the number of facilities, the number of operating organizations, the regulatory approach adopted and the legal arrangements in place [105]. A 1987 IAEA worldwide survey of 30 countries of bodies regulating nuclear reactors showed (Table 6) that the level of staffing of the regulatory body was generally between 5 and 25 professional staff for each reactor under the body's authority [106].

The IAEA report entitled Workforce Planning for New Nuclear Power Programmes [99] and the Guidebook for Manpower Development for Nuclear Power [100] concluded that, at the start of a nuclear power programme (e.g. site selection), the regulatory body should have a staff of about 25 professionals and reach a level of about 50 when the NPP starts to operate.

The necessary qualification of the regulatory staff is defined in the IAEA safety guide for Organization and Staffing of the Regulatory Body for Nuclear Facilities [105].

#### *3.5.1.4. Human resources in national nuclear industry*

Industry needs to participate in planning jointly with government and the owner/operator, and to provide, depending on the plan for national participation, trained personnel who will participate in the construction of the nuclear power facilities, including, for example, in site evaluation, civil and nuclear engineering, civil construction activities, and installation/erection, in fabricating and manufacturing (section 8 of Ref. [62]), during operation in maintenance and repair, and, in due course, in decommissioning.

As an example, during the installation of an NPP up to a peak value of 6000 workers, mainly (>80 %) trades/craftsmen and technicians, are needed on-site.

INPRO methodology has defined one criterion, CR4.1, for user requirement UR4 as set out in Table 7.

TABLE 7. CRITERIA FOR USER REQUIREMENT UR4

| User requirement | Criteria | Indicators (IN) and acceptance limits (AL) |
|---|---|---|
| UR4 Human resources:<br><br>The necessary human resources should be available to enable all responsible parties involved in a nuclear power programme to achieve safe, secure and economical operation of the NES during its lifetime | CR4.1: Human resources | IN4.1: Availability of adequate human resources to establish and operate an NES<br><br>AL4.1: Sufficient according to international experience |

### 3.5.2. Criterion CR4.1: Human resources

*Indicator IN4.1:* Availability of adequate human resources to establish and operate an NES.
*Acceptance limit AL4.1:* Sufficient according to international experience.

As mentioned earlier, all responsible parties involved in establishing, maintaining and expanding a nuclear power programme — government, operator of nuclear facilities and nuclear industry — need competent and trained human resources.

INPRO has specified several evaluation parameters for CR4.1 (human resources) as discussed below.

#### *3.5.2.1. Evaluation parameter EP4.1.1: Educational and training system for human resources needed in a nuclear power programme*

The availability of qualified human resources depends on having an effective education system in place. Various institutions are needed, ranging from universities to centres for training tradespeople (craftspeople) [107–109]). Relevant factors that need to be considered include the following: accessibility of the institutes to students (cost or other conditions); extent of nuclear specific training offered; qualification offered, i.e. diplomas, university degrees, certificates; and international recognition of the qualification.

To assess this EP the following questions (see section 1.2.5 of Ref. [62]) may be used by the INPRO assessor:

— Does the educational system offer qualifications at all three levels of training: skilled trades, technicians and professional engineers/scientists in all disciplines relevant to the nuclear community (government, industry and owner/operator)?
— Are the content and the standards of courses leading to these qualifications appropriate for the nuclear community?
— Are courses available, at each of the three levels, which are practically oriented and which include work experience appropriate to employment in the nuclear community?

A combination of domestic, regional, and international education arrangements should be used to secure a satisfactory level of education within the national workforce for the nuclear power programme (to be discussed further in user requirement UR6).

If a country is expanding its fleet of nuclear power reactors or replacing an old reactor with a new one at the end of its lifetime, the introduction of a different type of reactor into an existing national NES will have a significant impact on the effort to train/educate the necessary staff. Depending on the differences in design between the new and the existing reactors, the effort could become almost as great as introducing the first NPP into the country.

Acceptability of EP4.1.1 (condition for a positive judgement): Evidence is available to the INPRO assessor that a (qualitatively) adequate educational system exists (is planned).

#### *3.5.2.2. Evaluation parameter EP4.1.2: Adequate staff in nuclear institutions*

As stated above, all institutions involved in a nuclear power programme need adequate human resources to start, operate and decommission the nuclear facilities of an NES. The INPRO assessor is asked to check the (existing or planned) number and qualification of these human resources using relevant IAEA publications such as Refs [99, 102, 105].

Acceptability of EP4.1.2 (condition for a positive judgement): Evidence is available to the INPRO assessor that the necessary human resources are available (or planned) for the nuclear power programme.

#### *3.5.2.3. Evaluation parameter EP4.1.3: Attractiveness of the nuclear power sector for future employees*

Long term commitment to nuclear power by government and public acceptance thereof are important factors that individuals will take into account when deciding whether the nuclear field is attractive. Additional factors include salaries, working conditions, prospects for advancement, etc. These general workplace considerations need to be competitive when compared with other high tech industries. The two first aspects (long term commitment and public acceptance) have been addressed under UR3 and consequently the assessment of this evaluation parameter should focus on general workplace conditions.

Acceptability of EP4.1.3 (condition for a positive judgement)**:** Evidence is available to the INPRO assessor that attractive workplace conditions exist (are planned) comparable to those in other high-tech industries in the country.

*3.5.2.4. Final assessment of CR4.1: Human resources*

The acceptance limit AL4.1 (availability of adequate human resources to establish and operate an NES is sufficient according to international experience) of CR4.1 is met if the evaluation of all the EPs provided above has a positive result.

Assistance to INPRO assessors may be provided, if necessary, by the IAEA.

## 3.6. USER REQUIREMENT UR5: MINIMIZATION OF INFRASTRUCTURE

User requirement UR5 states: The NES should be designed to minimize the necessary infrastructure.

This user requirement is to be fulfilled by the designer (supplier) of NES facilities. The role of the INPRO assessor is to check whether the designer has succeeded in reducing the necessary infrastructure needed for a new facility in comparison to an existing (or reference) facility. In the updated INPRO methodology, 'an existing facility' is defined as 'a facility of latest design operating 2013' that can be used as a reference facility. It is obvious that the reference facility and the (new) facility being assessed should be from the same designer.

If the INPRO assessor is a technology user, he or she is assumed to prefer proven designs of nuclear facilities to be installed in his or her country, i.e. designs that have an existing reference facility already licensed and in operation. It is acknowledged that an INPRO assessor may have difficulties in collecting the necessary information for user requirement UR5 of such reference facilities (maybe also for the facilities to be installed). Therefore, to ease the collection of these data, in the overview manual of the INPRO methodology the INPRO assessor is recommended to enter into a cooperative arrangement with potential suppliers to obtain access to this information.

On the other hand, if the INPRO assessor is a technology developer, he or she should have no problem defining a suitable reference plant for the innovative design under development.

The question may be raised as to what innovations in the technical specification of an NES (or facility thereof) would diminish the need for (and cost of) various parts of the infrastructure. As an example, a maintenance free design (or one with significantly reduced maintenance) or a nuclear plant that technically would not need substantial emergency preparedness facilities or a large exclusion zone, or a nuclear plant with very slow transients that could be monitored remotely, would reduce the need for a corresponding infrastructure. Thus, designers may look at different types of innovation to drive down the cost of nuclear power in general and the cost of nuclear infrastructure in particular.

As required in the basic principle, a country embarking or running a nuclear power programme should not need an excessive investment in its nuclear infrastructure. Thus, this user requirement asks the designer to optimize the design of nuclear facilities to reduce the corresponding burden on the national nuclear infrastructure.

INPRO methodology has devised the following aspects of a nuclear infrastructure that could be influenced by the design of a facility:

— Amount of personnel needed to operate and perform maintenance and repair in and decommissioning of a nuclear facility;
— The extent to which prefabrication of components can be utilized to reduce construction works.

The first aspect is linked to the degree of automation or, vice versa, the need for manual operation, of a nuclear facility and its processes, which influences the necessary human resources to operate a plant. Future designs should use all reasonable possibilities of automation to reduce the need for operational personnel and should enable easy replacement/maintenance of equipment. Additionally, the designer of an (innovative) NES is requested to minimize the necessary additional staff for maintenance and repair, and to reduce the frequency of such activities.

The second aspect is related to the amount of work to be performed during the construction and erection of the facility. A higher degree of prefabrication in the country of origin could decrease the amount of human resources and some equipment needed at the construction site. It should be noted that a country may, however, be more interested in national participation in a nuclear power programme than in reducing the national contribution to such a programme.

An example of such a design, with a strongly reduced need for infrastructure, is a small reactor called a 'nuclear battery' [1110]. A second example is the SLOWPOKE heating reactor [111, 112]).

INPRO has formulated two criteria for UR5 covering the aspects discussed above which are shown in Table 8.

TABLE 8. CRITERIA FOR USER REQUIREMENT UR5

| User requirement | Criteria | Indicators (IN) and acceptance limits (AL) |
|---|---|---|
| UR5 Minimization of infrastructure:<br><br>The NES should be designed to minimize the necessary infrastructure | CR5.1: Personnel | IN5.1: Human resources needed for operation, maintenance and repair, and decommissioning<br><br>AL5.1: Amount is reduced in comparison with an existing facility |
| | CR5.2: Prefabrication | IN5.2: Extent of prefabrication of components<br>AL5.2: Extent is increased in comparison to an existing facility |

### 3.6.1. Criteria CR5.1 and CR5.2 for UR5

The assessment of the three criteria CR5.1 to CR5.3 could be performed in a simplified manner: the INPRO assessor should look for evidence (e.g. in form of a written argument) that the criteria CR5.1 to CR5.3 have been fulfilled. The evidence should be provided to the INPRO assessor by the designer/supplier of the NES facilities that are planned to be installed.

#### *3.6.1.1. Final assessment of CR5.1 and CR5.2*

The acceptance limits AL5.1 and AL5.2 of these two criteria, CR5.1 and CR5.2, are therefore met if evidence is available to the INPRO assessor that the designer/developer has decreased the necessary amount of infrastructure for the NES in comparison to existing designs.

It should be noted here that in the assessment of the second criterion, CR5.2, the policy of the country regarding national participation has to be taken into account, e.g. the country could prefer a higher national involvement in the construction work on-site instead of a product prefabricated abroad and delivered to the country.

It is expected that a designer will provide additional (or different) examples of how his or her design would reduce the necessary human resources.

## 3.7. USER REQUIREMENT UR6: REGIONAL AND INTERNATIONAL ARRANGEMENTS

User requirement UR6 states: Regional and international arrangements should provide options that enable a country with an NES to minimize the infrastructure for a nuclear power programme.

This user requirement is to be fulfilled primarily by the regional and global nuclear community. The role of the INPRO assessor is to check whether regional and/or global arrangements available to a country have been considered, which could reduce the national investment in infrastructure necessary for a nuclear power programme.

The user requirement UR6 encourages a country to consider international or regional solutions, in case the anticipated cost for (the necessary upgrade of) the infrastructure needed for the nuclear power programme is judged to be excessive. For example, the deployment of reactors in countries that can only afford a limited national nuclear infrastructure might be facilitated if the NES were owned and operated by an international nuclear utility (based on a BOO contract) or if it were so safe and easy to operate that it could be delivered as a 'black box nuclear battery'.

Even an established national infrastructure in a technology holder country might be evaluated using UR6, with the goal of optimizing the ongoing investment in national infrastructure, for example, by increasing the role of regional and international arrangements. For instance, global standardization of requirements and regulations (e.g. international or regional regulatory regimes and organizations) could facilitate cost reductions in such countries, by enabling assembly line type production for large series of plants.

One of the long term goals of the development of regional and international arrangements for nuclear related infrastructure is to reduce the necessary national investment to a level comparable to the investment needed in the infrastructure required for non-nuclear energy systems. For all infrastructure issues evaluated in user requirement UR1 to UR4, there is potential for regional or international arrangements that could be used to reduce the necessary effort for establishing and maintaining a nuclear infrastructure.

Thus, INPRO methodology has developed four criteria, CR6.1–CR6.4, for user requirement UR6, which are shown in Table 9.

TABLE 9. CRITERIA FOR USER REQUIREMENT UR6

| User requirement | Criteria | Indicators (IN) and acceptance limits (AL) |
|---|---|---|
| UR6 Regional and international arrangements:<br><br>Regional and international arrangements should provide options that enable a country with an NES to minimize the infrastructure for a nuclear power programme | CR6.1:<br>Options to reduce institutional infrastructure | IN6.1: Have regional and/or international arrangements to reduce the institutional infrastructure been considered?<br><br>AL6.1: Yes |
| | CR6.2:<br>Options to reduce industrial infrastructure | IN6.2: Have regional and/or international arrangements to reduce the industrial infrastructure been considered?<br><br>AL6.2: Yes |
| | CR6.3:<br>Options to reduce social political infrastructure | IN6.3: Have regional and/or international arrangements to reduce the social political infrastructure been considered?<br><br>AL6.3: Yes |
| | CR6.4:<br>Options to reduce human resources | IN6.4: Have regional and/or international arrangements to reduce the necessary human resources been considered?<br><br>AL6.4: Yes |

### 3.7.1. Criterion CR6.1: Options to reduce investment in institutional infrastructure

*Indicator IN6.1:* Have regional and/or international arrangements to reduce the institutional infrastructure been considered?
*Acceptance limit AL6.1:* Yes.

Two main developments could affect the existing institutional structures with beneficial effects, namely simplification and international harmonization of licensing, thereby fulfilling the infrastructure user requirement UR6, i.e. minimizing the infrastructure.

In the first place, the development of an NES to comply with all the INPRO basic principles, requirements and criteria in all methodology areas could make it possible to change the way the use of nuclear energy is regulated. When, for example, the financial and safety risk from NES are comparable to that of industrial facilities used for similar purposes,' and 'there is no need for relocation or evacuation measures outside the plant site, apart from those generic emergency measures developed for any industrial facility, the requirements for licensing could possibly be changed and simplified. Thus, as NESs that meet all the INPRO methodology requirements are realized, the existing legal structures for licensing NES could and should be re-evaluated. This arrangement is to be realized primarily in a country with a nuclear power programme in operation.

Secondly, globalization and internationalization of the markets for energy as well as for energy equipment (e.g. power plants) could influence the existing legal structures governing the deployment of nuclear energy. In a world that is becoming more globalized with a growing need for sustainable energy, harmonization of regulations and licensing procedures could facilitate the application of nuclear technology. Such harmonization between different markets is in the interest of suppliers and developers of technology as well as users. Establishing a harmonized licensing system (or, alternatively, reaching agreements that national licenses are accepted internationally) requires an international agreement on the basis for licensing. Agreement already exists to some extent and is reflected in international conventions, standards, and guides, but enhanced international cooperation will be necessary to achieve the degree of harmonization that should be possible. National governments have a duty to assure the safety and security of their populations and protection of the environment. It can be anticipated that governments will become more amenable to accepting international regulations and procedures as the risks (perceived by the public) and potential adverse effects of nuclear power are diminished.

The process of harmonization of licensing has already started by cooperation between individual supplier and user countries. An example of such a harmonization programme already in operation is the organization WENRA (Western Europe Nuclear Regulatory Agency) which was founded in 1999 and includes regulatory bodies from 17 EU countries. An international activity in this area is MDEP (Multinational Design Evaluation Programme) established in 2006, an OECD operated programme with 12 countries as participants. It is expected that suppliers, investors and international operators of NESs would find it advantageous to agree to a licensing mechanism whereby once a given NES had been licensed, on the basis of meeting agreed regulations, standards and requirements, the license would be valid in any country where the system might be deployed. Such a development would also seem to be advantageous to Member States in which the system would be used. Conditions for the realization of such developments include the absence of trade barriers that impede such international cooperation and acceptance by national regulators and politicians.

Since the development of national legal structures and the technical competence required to utilize these structures effectively requires a major effort, it would make sense for countries that are interested in acquiring nuclear energy to cooperate with like-minded countries, perhaps regionally, and so share the cost of developing the necessary infrastructure. Such regional cooperation could be even more advantageous as responsibility for energy supply moves from the public sector to national or international private sector companies.

The IAEA has prepared a publication that provides guidance on the potential for sharing nuclear power infrastructure among countries adopting or extending a nuclear power programme (see Ref. [78]). The viability of sharing facilities for the disposal of spent fuel and nuclear waste is evaluated in an IAEA report [113].

#### *3.7.1.1. Final assessment of CR6.1: Options to reduce investment in institutional infrastructure*

The acceptance limit AL6.1 (Have regional and/or international arrangements to reduce the institutional infrastructure been considered?) is met if there is evidence available to the INPRO assessor that the national regulatory body has considered all available options.

### 3.7.2. Criterion CR6.2: Options to reduce industrial infrastructure

*Indicator IN6.2:* Have regional and/or international arrangements to reduce the industrial infrastructure been considered?
*Acceptance limit AL6.1:* Yes.

For the industrial infrastructure, regional or international sharing of the necessary support industry could reduce the necessary national investment into infrastructure. For countries that need only a small number of NPPs, it may not be cost effective or necessary to develop a fully capable domestic nuclear supply or support structure. In such countries, international operating companies that can provide most of the necessary infrastructure for building, owning and operating nuclear power systems, could supply a valuable service by offering suitable contracts (BOO or BOT).

Optimization of a global NES will be fostered when nuclear facilities of the front and back end of the fuel cycle, located in different countries, are viewed as part of an international multi-component system. A healthy international commercial market exists for the supply of fuel, thus obviating the need for a country to invest in the front end. Waste management, however, remains a national responsibility. But in due course, international arrangements might be developed to enable other options such as the return of spent fuel to its country of origin or sharing of disposal facilities. In the future, provided the legal frameworks[39] could be adjusted accordingly, international operating companies could assume a growing role in realizing such an approach.

*3.7.2.1. Final assessment of CR6.2: Options to reduce industrial infrastructure*

The acceptance limit AL6.2 (Have regional and/or international arrangements to reduce the industrial infrastructure been considered?) is met if there is evidence available that the national industry and the owner/operator has considered all available options.

### 3.7.3. Criterion CR6.3: Options to reduce social political infrastructure

*Indicator IN6.3:* Have regional and/or international arrangements to reduce the social political infrastructure been considered?
*Acceptance limit AL6.3:* Yes.

One area where international cooperation can contribute to an improvement of public acceptance of nuclear power is the application of standards. It is of the greatest importance to apply internationally acceptable standards of safety, security and environment to nuclear projects and operations. Harmonization among countries in the main standards and in safety and security culture procedures covering aspects of waste management and environmental protection could positively influence public opinion of nuclear power. Ways need to be found to facilitate the application of such standards globally by making available the necessary knowledge to all countries, including developing countries that do not have the means to develop such standards themselves.

*3.7.3.1. Final assessment of CR6.3: Options to reduce social political infrastructure*

The acceptance limit AL6.3 (Have regional and/or international arrangements to reduce the social political infrastructure been considered?) is met if there is evidence available to the INPRO assessor that the regulator and the national industry has considered all available options.

### 3.7.4. Criterion CR6.4: Options to reduce human resources

*Indicator IN6.4:* Have regional and/or international arrangements to reduce human resources been considered?
*Acceptance limit AL6.4:* Yes.

Globalization brings with it the opportunity to draw on a much broader pool of resources rather than striving to maintain a complete domestic capability across the many disciplines of science and engineering that constitute the range of technologies on which NESs depend. International cooperation in science and development can assist with optimizing the deployment of scarce human resources and, just as important, the construction and operation of large scale research and engineering test facilities. Enhanced cooperation in the field of enabling technologies and the use of advanced developments from other industries could also contribute. Companies operating on a global basis can develop specialist teams that provide services (e.g. for maintenance and repair) to operating plants in many different countries.

In the area of human resources, the establishment of the World Nuclear University [114] with support from the IAEA helps to retain existing knowledge and experience by sharing science and development activities. Use of such global arrangements can reduce the necessary national effort for an adequate educational system.

[39] Currently, most countries do not allow the return of spent fuel or radioactive waste created outside their borders.

*3.7.4.1. Final assessment of CR6.4: Options to reduce human resources*

The acceptance limit AL6.3 (Have regional and/or international arrangements to reduce the human resources been considered?) is met if there is evidence available to the INPRO assessor that the government, and the owner/operator has considered all available options.

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# GLOSSARY

**assessment.** An assessment using the INPRO methodology is a process of making a judgement about the long term sustainability of a nuclear energy system. In principle, analyses using analytical tools are not part of an INPRO assessment but could provide necessary input for the assessment. The assessment of a nuclear energy system is performed at the criterion level of the INPRO methodology. In the case of a numerical criterion, the assessment process consists of a comparison of the value of an indicator with the value of the acceptance limit of a criterion. In the case of a logical criterion — mostly phrased in the form of a question — the assessment is performed by answering the question raised.

**assessor.** The INPRO assessor is an expert or a team of experts applying the INPRO methodology in a nuclear energy system assessment. He or she is typically a member of a national academic society or an investigator at a nuclear research centre, but could also be employed by a utility or an organization of the regulator or supplier.

**basic principle (BP).** The BP of each publication of the INPRO methodology is a statement of a general goal that must be achieved in a nuclear energy system to be sustainable in the long term, and provides broad guidance for the necessary development (or a design feature thereof). The wording of a basic principle always utilizes the verb ‘shall’ or ‘must’.

**criterion (CR).** A CR enables the INPRO assessor to determine whether and how well a user requirement is being met by a given nuclear energy system. A criterion consists of an indicator (IN) and an acceptance limit (AL). INs may be based on a single parameter, on an aggregate variable or on a status statement. ALs could be international or national regulatory limits or defined by the INPRO methodology. Two types of criteria are distinguished: numerical and logical. A numerical criterion has an IN and AL that is based on a measured or calculated value that reflects a property of an NES. A logical criterion is associated with some important feature of (or measure for) an NES and is usually presented in form of a question that has to be answered positively. Some criteria are associated with evaluation parameters to simplify the assessment process.

**evaluation parameters (EP).** These INPRO methodology parameters were introduced to assist the INPRO assessor in determining whether a criterion has been met. In some cases, these evaluation parameters have their own acceptance limits, in which case they could be called sub-indicators.

**evolutionary design.** This is an advanced design that achieves improvements over existing designs through small to moderate modifications, with a strong emphasis on maintaining design features that are proven to minimize technological risks. Examples of evolutionary reactors are Generation III or Generation III+ reactors.

**existing facility.** A facility or a nuclear energy system that is of the latest design and operating in 2013. This existing facility is used in the INPRO assessment as a reference facility to be compared to the facility being assessed.

**holistic.** The INPRO methodology is defined as a holistic approach to achieve the long term sustainability of a nuclear energy system. Holistic means that all aspects of a nuclear power programme must be considered up to 2099, a complete fuel cycle of an NES during the lifetime of all its facilities, covering all areas of the INPRO methodology from economics to safety.

**innovative design.** This is an advanced design, which incorporates radical conceptual changes in design approaches or system configuration in comparison with existing practice. These systems may comprise not only electricity generating plants, but include also plants (of various size and capacity) for other applications, such as high temperature heat production, district heating and sea water desalination, to be deployed in developed regions as well as in developing countries and countries in transition. Examples of innovative reactors are Generation IV reactors.

**nuclear energy system (NES).** A nuclear energy system comprises the complete spectrum of nuclear facilities and associated legal and institutional measures (infrastructure). In addition to nuclear reactors, nuclear facilities include those for: mining and milling, refining, conversion and enrichment of uranium, manufacturing of nuclear fuel, reprocessing of nuclear fuel (if a closed nuclear fuel cycle is used), and facilities for related materials management activities, including transportation and waste management (storage and disposal). Legal measures consist of the national nuclear law and international agreements, treaties, and conventions, and institutional measures include the corresponding national institutions such as regulatory bodies.

**proven technology.** A technology for which a reference plant is already successfully in operation. Nuclear technology users are assumed to prefer proven technology for installations in their own countries.

**sustainability.** In the INPRO methodology, to confirm the sustainability of an NES, the system must be capable of operating at least until 2099.

**user requirement (UR).** A UR defines what should be performed to meet the target/goal of the INPRO methodology basic principle and is directed at specific institutions (users) involved in nuclear power development, deployment and operation, i.e. developers/designers, government agencies, facility operators, and support industries. The wording of a user requirement utilizes the verb ‘should’.

## ABBREVIATIONS

| | |
|---|---|
| AL | acceptance limit (INPRO methodology) |
| BOO | build, own and operate |
| BOT | build, own and transfer |
| BP | basic principle (INPRO methodology) |
| CR | criterion (INPRO methodology) |
| EP | evaluation parameter (INPRO methodology) |
| EPR | Emergency Preparedness and Response |
| EPREV | Emergency Preparedness Review Service |
| IN | indicator (INPRO methodology) |
| INIR | Integrated Nuclear Infrastructure Review (IAEA) |
| INPRO | International Project on Innovative Nuclear Reactors and Fuel Cycles (IAEA) |
| INSServ | International Nuclear Security Advisory Service (IAEA) |
| IPPAS | International Physical Protection Advisory Service (IAEA) |
| IRRS | Integrated Regulatory Review Service (IAEA) |
| ISSAS | IAEA State system for accountancy and control of nuclear material advisory service |
| JVC | joint venture company |
| MDEP | Multinational Design Evaluation Programme (OECD) |
| NES | nuclear energy system |
| NPES | Nuclear Power Engineering Section (IAEA) |
| NPP | nuclear power plant |
| NPT | Non-Proliferation Treaty |
| NRC | Nuclear Regulatory Commission (United States of America) |
| OECD | Organization for Economic Co-operation and Development |
| OLA | Office of Legal Affairs (IAEA) |
| PESS | Planning and Economics Studies Section (IAEA) |
| SEA | Strategic Environmental Assessment |
| SEED | Site and External Events Design Review Service (IAEA) |
| SSAC | State system of accountancy and control of nuclear material |
| UNECE | United Nations Economic Commission for Europe |
| UR | user requirement (INPRO methodology) |
| WENRA | Western Europe Nuclear Regulatory Agency |

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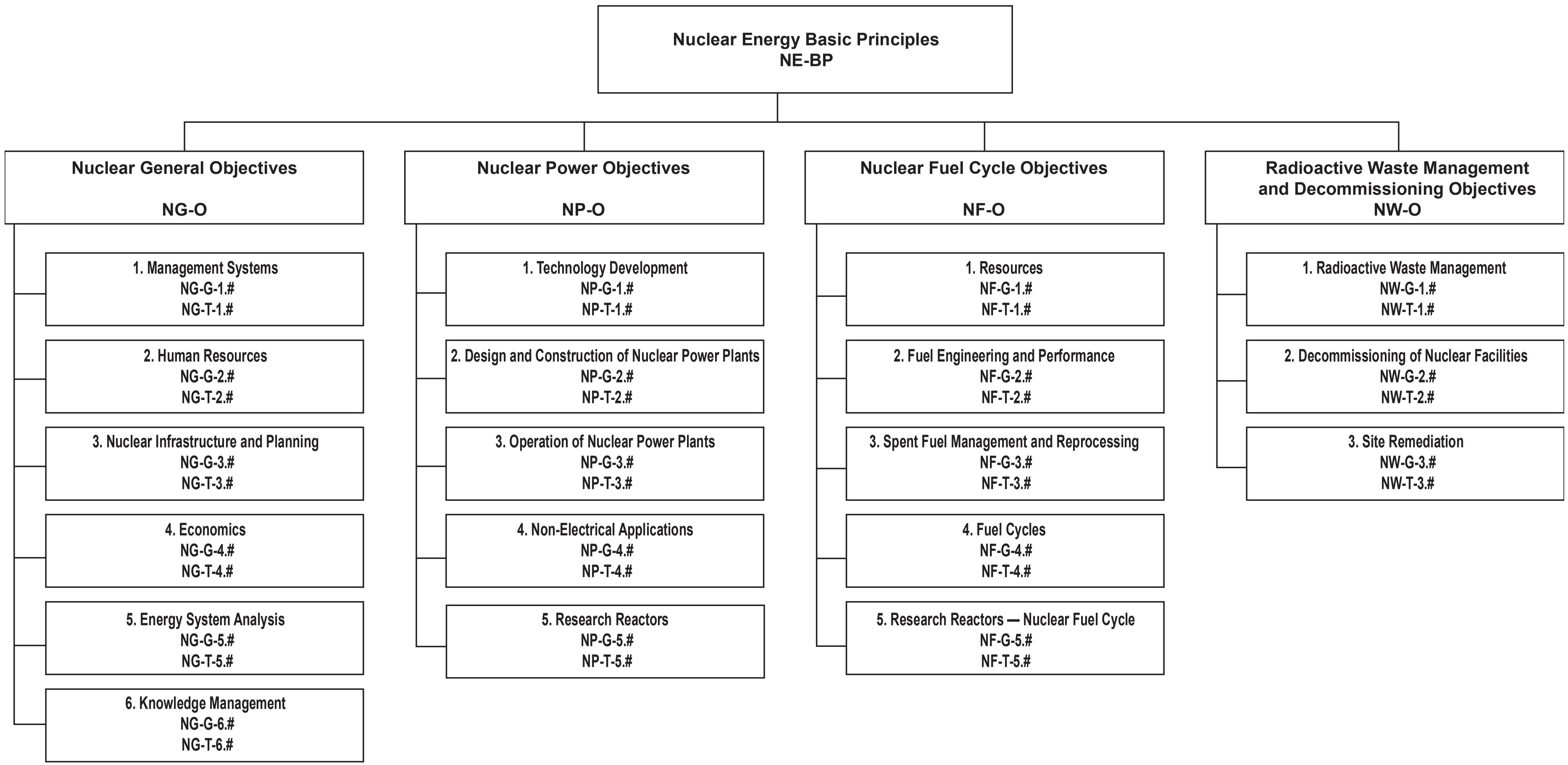


*Key*

**BP:** Basic Principles
**O:** Objectives
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**Nos 1-6:** Topic designations
**#:** Guide or Report number (1, 2, 3, 4, etc.)

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