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## METHODOLOGY FOR INNOVATIVE NUCLEAR TECHNOLOGIES ASSESSMENT

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### Abstract

In order to bring together IAEA Member States interested in developing nuclear power (both producers and consumers), a consensus on the joint development of nuclear power as one of the energy systems for the future is recommendable.

The INPRO project aims at providing a platform for such a consensus. Under the INPRO Terms of Reference, for innovative nuclear technologies the user requirements are being established as a first step. This will be followed by the design of the technology assessment method. Finally, Member States will do the assessment of different innovative nuclear technologies against the established users' requirements. This should make it possible for the Member States to decide which technology fulfills their future needs best.

The INPRO report describes the issues related to the definition of the requirements, assessment criteria and processes proposed for usage in the INPRO project.

The methodology for assessing innovative nuclear technologies – referred to as the “**INPRO Methodology**” - should help in the selection of suitable development paths for the future nuclear power systems with their associated fuel cycles. The INPRO Methodology will provide a tool to identify all components needed for a future nuclear power system and to organize the scientific research work needed to improve its existing components and develop missing components. It will take into account foreseeable changes in the requirements and conditions under which nuclear power will be developed and operated in the future. In designing this INPRO Methodology, regional and other specific requirements will be included, where possible, examples will be provided, and it will be pursued in a continuously improving process.

The INPRO Methodology follows a “top-down” method and has a logical hierarchy of its assessment process. Its multilevel system includes 1) User Requirements in the areas of economics, environment, safety and proliferation resistance, 2) Approaches to meet all User Requirements, 3) Evaluation Criteria, 4) Indicators to check the compliance with each of the Evaluation Criteria.

In order to guarantee easy understandable results of the INPRO Methodology for the assessment process the following judgment will be used for the outcome of the technology evaluation against each specific criterion defined in the INPRO project: very high potential to satisfy the criterion; high potential to satisfy the criterion; potential to satisfy the criterion; no potential to satisfy the criterion.

In general, nuclear technology assessment should focus on finding technology options able to satisfy all User Requirements. It can be expected, that different nuclear technology concepts will be needed to create nuclear power systems able to meet the differentiated requirements of the various regions.

## INTRODUCTION

In order to bring together IAEA Member States interested in developing nuclear power (both producers and consumers), a consensus on the joint development of nuclear power as one of the energy systems for the future is recommendable. The INPRO project aims at providing a platform for such a consensus. Under the INPRO Terms of Reference, for innovative nuclear technologies the user requirements are being established as a first step. This will be followed by the design of the technology assessment method. Finally, Member States will do the assessment of different innovative nuclear technologies against the established users' requirements. This should make it possible for the Member States to decide which technology fulfills their future needs best.

The paper describes the issues related to the definition of the requirements, assessment criteria and processes proposed for usage in the INPRO project.

### **Goals and reasons for the development and adoption of the INPRO Methodology**

In elaborating international recommendations for the large-scale development of nuclear power we have to select the optimum path of development from now on until, say, the middle of this century. There may therefore be a need in the near future for the joint development and demonstration of nuclear technologies, which will become fundamental to subsequent large-scale development.

Lengthy periods of time and significant resources are required for the development of new technologies and the corresponding industrial infrastructure. Errors in the selection of the development path for innovative nuclear technologies at the early stages could impact on the viability of nuclear power. To avoid such errors, we must assess and select technologies for subsequent international study and application **with a view to creating a global nuclear power infrastructure, which would enable the world community to make the transition to sustainable development.** A special methodology is needed for these purposes.

The methodology for assessing innovative nuclear technologies – referred to as the “**INPRO Methodology**” - should help in the selection of suitable development paths for the future nuclear technologies (power systems with their associated fuel cycles). The INPRO Methodology will provide a tool to identify all components needed for a future nuclear power system and to organize the scientific research work needed to improve its existing components and develop missing components. It will take into account foreseeable changes in the requirements and conditions under which nuclear power will be developed and operated in the future. In designing this INPRO Methodology, regional and other specific requirements will be included, where possible, examples will be provided, and it will be pursued in a continuously improving process.

### **Basic features of the INPRO Methodology for innovative nuclear technologies assessment**

The INPRO Methodology follows a “top-down” method (1) and has a logical hierarchy of assessment process. Its multilevel system includes 1) **User Requirements** in

the areas of economics, environment, safety, proliferation resistance and cross-cutting issues, 2) **Approaches** to meeting all User Requirements, 3) Evaluation **Criteria**, 4) **Indicators** to check the compliance with each of the Evaluation Criteria.

**Definitions** of these terms have been presented at ICONE10 conference (1). In the following additional details concerning these issues and the proposed evaluation scheme are given.

The INPRO Methodology has the following features:

- The Methodology incorporates as far as possible the results applicable from similar activities at the international and national levels.
- The Methodology is oriented more to find a range of technology alternatives being able to meet user requirements than to select only the “best” one.
- The methodology will be able to take into account different technical, sociological and economical factors that will influence the future of nuclear power, the different approaches to meet the requirements, implementation risk, as well as national or regional features.

### **Sphere of application and recommendations for the use of the INPRO Methodology**

It would be advisable to have a general agreed procedure for use of the INPRO Methodology, including recommended guidelines for its application, standardized criteria, possible quantitative characteristics, etc.

Regarding INPRO objectives, it is expedient for the time being to limit us to a set of high level user requirements and criteria and to place emphasis on those, based on physical principles. Additional specific User Requirements and national/international Criteria, taking into account the differentiated requirements of the various regions and countries, shall be added at later stages of the INPRO project.

Innovative nuclear technologies will be assessed by experts against relevant technical parameters. Existing technologies and plans for their evolutionary development must also be assessed against relevant parameter, but taking into account operational experience and achieved results. In any expert comparison of existing/evolutionary technologies and innovative Approaches, the **expected** parameter must get the best judgment. Correctly formulated requirements and a methodology for comparison of innovative technologies constitute a development path and not a screening mechanism for technologies of as yet unproven worth.

In general, nuclear technology assessment should focus on finding technology options able to satisfy all User Requirements. It can be expected, that for future nuclear energy systems, a number of different nuclear technology concepts (Approaches) will be needed to meet the differing preferences regarding the requirements of various regions. For each Approach (concept) a set of different Criteria with associated Indicators might be needed to be developed.

### **User requirements.**

The **USERS' REQUIREMENTS** are the conditions, which have to be met to achieve user acceptance of innovative nuclear power technologies. The concept “user requirements” includes the following concepts:

**A USER** is an entity that has a stake or interest in particular sectors where nuclear technologies are potentially applicable. **USERS** comprise both the society and the industry

Typical examples of users (persons or groups with an “interest” in future nuclear technology development), acting as players in the process of putting forward requirements for the development of innovative nuclear technologies are as follows (in no particular order of importance) :

- Designers who put forward and elaborate new requirements;
- Regulatory bodies, local representatives and selected authorities, national governments and local administrations, non-governmental organizations and the press, and international organizations which have an influence on the elaboration of requirements.

### **Approaches to meeting the requirements**

The Approach is the proposed technical or institutional mechanism for meeting User Requirements by means of appropriate steps in all areas (technology development, political or institutional measures).

Technical Approaches (nuclear technologies – energy systems and their fuel cycle facilities) should be considered dependant on a stage of their development. For example they can be grouped as following:

**Group 1** - existing commercial technologies making a significant contribution to energy production.

**Group 2** - technologies under development for which there is still no industrial infrastructure and which do not as yet play a significant role in energy production.

**Group 3** - technologies proposed for development, for which only individual features and application prospects have been claimed so far. Time and resources will be needed to set up demonstration models

The grouping will make an influence on the final judgment of the fulfillment of the Criteria.

As was mentioned above it would hardly be possible to find all preferences for all User Requirements in the different areas. It may be expected that more than one concept of future nuclear energy technology may be good enough to meet sufficiently all relevant requirements or several User Requirements.

It may be recommended that the proposals on Approaches (including if possible enabling technologies) to meet User Requirements should be prepared with broad participation of experts from INPRO Member States. No Approaches should be excluded from further consideration.

Institutional Approaches include Institutional arrangements, such as safeguards or extrinsic measures for innovative nuclear systems in proliferation resistance area, and other principles, such as Continuity and Step-by-step principle

### **Criteria and Indicators**

**A CRITERION** is a principle or standard used to judge of a matter.

A criterion is the product of reasoned interpretation and analysis of past experience and past conditions, on the assumption that conditions in the future will not change to such an extent that past experience and past achievements will no longer be valid. Criteria are a kind of concentrated experience that helps us choose correctly.

The Criteria should be established in such a way that the fulfilment of all Criteria for a certain Approach (set of Approaches) should ensure that the relevant User Requirement is met. As was mentioned above, in case there is more than one Approach to meet a User Requirement, separate Criteria with associated Indicators for each Approach will need to be established.

**An INDICATOR** (Condition Indicator) is a characteristic of a structure, system or component (nuclear technology option) that can be observed, measured or trended to infer or directly indicate the current and future ability of the structure, system or component to function within acceptance Criteria. Functional Indicator is a condition indicator that is a direct indication of the current ability of a structure, system or component to function within acceptance Criteria.

In the nuclear power field to day, the technical Criteria and specifications for PWRs, BWRs, HWRs and AGRs have been studied in greater detail than those for FRs and HTGRs. These Criteria are perfectly adequate for the purposes of comparison of power reactors, which are evolutionary developments of these types of reactors. However, when developing innovative designs they can serve only as an example for the development of systems of standards, requirements and rules based on the top-level requirements and calling for strict implementation.

When necessary (for example in case of Criteria concerning environmental influence or evaluation of external costs) Criteria should include the description of method or standards according to which the assessment should be done. These methods of assessment should be agreed with INPRO Member States.

The following principles are recommended for the establishing of the evaluation Criteria and their associated Indicators:

- The Criterion and corresponding Indicator should be established for all user requirements;
- To the extent possible, the Criterion should be common to all Approaches. When there is more than one Approach to meet the User Requirements, separate Criteria and Indicators may need to be established for each Approach;
- Where possible, the Criterion should be prescriptive;
- For each Criterion there should be one or more associated Indicators;

Wherever possible, Indicators should be measurable and quantifiable, as well as logically independent.

Fragmental examples of Criteria and Indicators for different Approaches to meeting top-level User Requirements in the areas of safety and environment are given in Tables 1.

### **Assessment and judgement process**

In order to guarantee easy understandable results of the INPRO Methodology for the assessment process the following judgment will be used for the outcome of the technology evaluation against each specific Criterion defined in the INPRO project: Very High potential to satisfy the criterion; High potential to satisfy the criterion; Potential to satisfy the criterion; No Potential to satisfy the criterion.

### **Next steps**

It is natural to assume that a global nuclear power system will result from the development of national (State) and regional (inter-State) nuclear power systems.

The selection of an infrastructure for a regional system, and of its component elements, should always be preceded by strategic monitoring of the development of the power sector in the context of the general strategy for sustainable development of a region as part of a global process. This stage in the process of creating the system is very important. Therefore incorporation of regional and national aspects into the INPRO Methodology will be the next milestone of its design.

A Case study is to be performed and will be conducted by INPRO Task groups with broad participation of experts from Member State. It should be based on technical Criteria, elaborated during INPRO implementation, as well as the technology option input from one or several Member States. It may be advisable, that Member States should present the information on technology option to be assessed in a form suitable for evaluation against the selected set of Criteria.

Finally, the Methodology and guidelines for innovative technologies assessment against User Requirements will be prepared and the assessments will be performed by Member States to decide which technology fulfills their future needs best.

Table 1 INPRO Methodology. Fragmental example in the area of Safety

INPRO Requirements in the area of Safety	Use	Approaches (common to all requirements)	Criterion	Indicator
1. The innovative nuclear energy systems shall be so safe that they can be sited in locations similar to other industrial facilities		Development of different innovative nuclear energy systems: with: • <i>Increased emphasis on inherent safety characteristics</i> • <i>Enhancement of defence in depth features</i> •	Dose limits to be defined by regulatory bodies	Exposure doses due to releases of radioactive materials and other hazardous materials
2. The innovative nuclear energy systems shall have a lower risk associated with fuel damage than current plants		and having - <i>Simplified designs,</i> - <i>Improved materials,</i> - <i>Reliable decay heat removal system,</i> - <i>Highly reliable control systems,</i> - <i>Robust and tight containment system</i>	Core damage probability at least 10 times* less than accepted values for existing NPPs (*) to be defined	Core damage probability

## References

1. V. Kagramanyan, A.Garmash “The Methodology For Innovative Nuclear Technology Evaluation”. Proceedings ICONE10-22504. 10<sup>th</sup> International Conference on Nuclear Engineering, Arlington, VA April 14-18, 2002

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