Development of INPRO methodology in the area of Environment

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INTRODUCTION

The IAEA International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) aims at providing a framework for assessing the sustainability of Innovative Nuclear Energy System (INS) in fulfilling the energy needs in the 21st century, and make it available to all relevant stakeholders at national as well as regional and international level.

INPRO METHODOLOGY

The INPRO methodology is described in [1]. It covers all areas or dimensions that have been identified as characterizing a sustainable performance of nuclear energy systems, namely: economics, safety of nuclear installations, environment, waste management, proliferation resistance, and national, regional and international infrastructure. A set of Basic Principles (BP), User Requirements (UR), and Criteria (CR), the latter consisting of Indicators (IN) and Acceptance Limits (AL), has been defined for each area. A hierarchy of these elements in the INPRO methodology is shown in Fig. 1.

The area of environment has defined two BPs, one covering the acceptability of expected adverse environmental effects, the other addressing the fitness for purpose, which are shown with the associated URs, INs and ALs in Table 1 and 2, respectively [1].

INPRO MANUAL

To enable users to apply the INPRO methodology to actual cases, a manual has been developed, which includes separate chapters on the INPRO areas: economics, safety, infrastructure, waste, proliferation resistance and environment. Each chapter includes a description of how to determine the indicators of the relevant INPRO area for a given INS, and provide examples of evaluations and corresponding acceptance limits.

THE ENVIRONMENT CHAPTER OF THE INPRO MANUAL

The environment chapter of the INPRO manual aims at providing practical guidance on how to assess the INs and ALs shown in Table 1 and 2. The methodology proposed for the comprehensive environmental assessment of INPRO is innovative as a whole, although based on different existing technical approaches and current practice. The chapter includes the description of the steps necessary to perform an adequate assessment, specific methodologies, suitable existing tools, documentation of calculations, data sources and examples of environmental assessment of current and innovative nuclear energy technologies. The assessment includes effects on human health and biota species. Both radiological and non-radiological effects are considered. The guidance was developed to be applicable to any kind of INS facilities for a wide range of technical maturity levels, to take into account different developmental stages of INSs.

FURTHER DEVELOPMENT

Although the INPRO manual has been created and reviewed in a concerted effort by several selected international experts, it is at present still at an early stage of development and shall be considered working material. INPRO Members have been performing assessment studies of INSs of own interest, using the INPRO methodology independently and/or jointly, and the manual has been tested by these actual applications. All chapters will be revised and refined based on the feedback from the assessment studies, then the manual will be released to the public.

REFERENCES

1. IAEA, "Methodology for the assessment of innovative nuclear reactors and fuel cycles – Report of Phase 1B (first part) of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)," IAEA-TECDOC-1434, Vienna (2004).

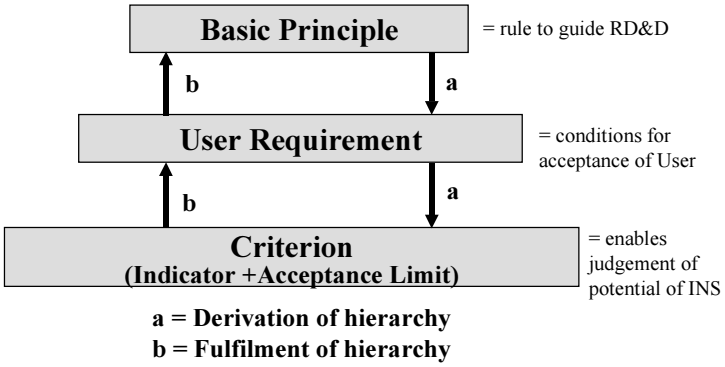

Figure 1 INPRO hierarchy of demands on assessment of Innovative Nuclear Energy Systems (INS)

Table 1 INPRO methodology in the area of Environment (BP1) [1]

Environmental Basic Principle BP 1:(Acceptability of Expected Adverse Environmental Effects) *The expected (best estimate) adverse environmental effects of the innovative nuclear energy system shall be well within the performance envelope of current nuclear energy systems delivering similar energy products.*		
User Requirements	Criteria	
	Indicators	Acceptance Limits
UR 1.1 *The environmental stressors from each part of the INS over the complete life cycle should be controllable to levels meeting or superior to current standards.*	1.1.1: L_{St-i}, level of stressor i.	1.1.1: $L_{St-i} < S_i$, where S_i is the standard for stressor i.
UR 1.2 *The likely adverse environmental effects attributable to the INS should be as low as reasonably practicable, social and economic factors taken into account.*	1.2.1: Does the INS reflect application of ALARP to limit environmental effects?	1.2.1: Yes.

Table 2 INPRO methodology in the area of Environment (BP2) [1]

Environmental Basic Principle BP 2:(Fitness for Purpose) *The INS shall be capable of contributing to the energy needs in the 21st century while making efficient use of non-renewable resources*		
User Requirements	Criteria	
	Indicators	Acceptance Limits
UR 2.1 *(Consistency with Resource Availability)* *The INS should be able to contribute to the world's energy needs during the 21st century without running out of fissile/fertile material and other non-renewable materials, with account taken of reasonably expected uses of these materials external to the INS. In addition, the INS should make efficient use of non-renewable resources.*	2.1.1: F_j (t) : quantity of fissile/fertile material j available for use in the INS at time t.	2.1.1: F_j (t) > 0 $\forall$ t < 100 years*
	2.1.2: Q_j (t) : quantity of material i available for use in the INS at time t. 2.1.3: P (t): power available (from both internal and external sources) for use in the INS at time t.	2.1.2: Q_j (t) > 0 $\forall$ t < 100 year 2.1.3: P(t) ≥ P_{INS}(t) $\forall$ t < 100 years, where P_{INS}(t) is the power required by the INS at time t.
	2.1.4: U : end use (net) energy delivered by the INS per Mg of uranium mined 2.1.5: T : end use (net) energy delivered by the INS per Mg of thorium mined. 2.1.6: C_i : end use (net) energy delivered per Mg of limited non-renewable resource consumed	2.1.4: U > U0 U0 : maximum achievable for a oncethrough PWR. 2.1.5: T > T0 T0 : maximum T achievable with a current operating thorium cycle. 2.1.6: C_i > C0 C0 to be determined on a case specific basis.
UR 2.2 *(Adequate Net Energy Output)* *The energy output of the INS should exceed the energy required to implement and operate the INS within an acceptably short period.*	2.2.1: T_{EQ} : time required to match the total energy input with energy output (yrs).	2.2.1: $T_{EQ} < k \cdot T_L$ T_L : intended life of INS k < 1

* "F_j (t) > 0 $\forall$ t < 100 years" reads like: F_j (t) must be greater than zero for any time t less than 100 years.