# Study on GIF PR/PP Evaluation Methodology

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## 1. Introduction

Proliferation resistance (PR) and physical protection (PP) is one of the four technology goals of generation IV nuclear energy systems (NESs). The PR component of the goal focuses on providing strong assurance that generation IV NESs are the least desirable sources for the diversion or undeclared production of nuclear materials, whereas the PP portion of the goal ensures that generation IV NESs are robust against theft and sabotage. In 2002, the roadmap of the Generation IV International Forum (GIF) envisioned that the R&D program for PR&PP would have three areas: 1) safeguards and physical protection technology R&D for each GIF system; 2) formulation of PR&PP criteria and metrics; and 3) evaluation of the criteria and metrics [1].

To cover these R&D items, the PR&PP Working Group (PRPPWG) was formed in late 2002 and has since developed a methodology for PR&PP evaluation. In a succession of revisions beginning in 2004, consensus was achieved amongst all participating GIF countries and related organizations (i.e., IAEA and EU), and Revision 6 of the methodology report was approved by GIF for open distribution in 2011 [2]. The paper describes in detail the methodology developed by the PRPPWG and discusses its applicability to the sodium-cooled fast reactor (SFR) fuel cycle with pyroprocessing currently under development in Korea.

## 2. PR&PP Evaluation Methodology

As shown below, the evaluation methodology developed by the PRPPWG comprises three steps: (1) define a set of challenges; (2) analyze the system response to these challenges; and (3) assess outcomes.

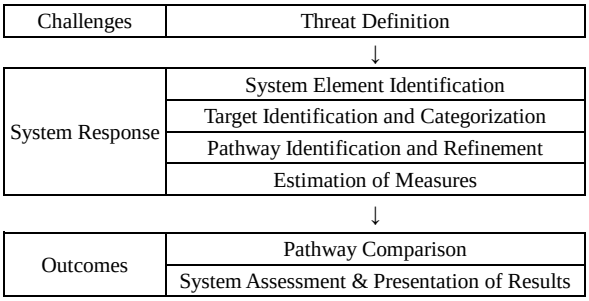


Fig.1. Framework for PR&PP evaluation methodology.

### *2.1 Challenges*

To evaluate PR&PP, analysts must first determine against whom and against which actions the NESs are being protected. The results of the evaluation can only be properly understood in this context. In order to be comprehensive, a full range of potential threats, referred to as the reference threat set (RTS), must be recognized and evaluated. This requires rigid definition of each threat as well as the ability to predict and respond to potential threats that may not yet have been encountered. RTS should evolve through the design and development process of nuclear facilities, which ultimately may contribute to the formulation of a design basis threat (DBT) upon which regulatory action can be based.

### *2.2 System Response*

To analyze the system response, a pathway analysis method is used, whose four steps are given below:

- System element identification. In this step, the NES is decomposed into smaller elements or subsystems (e.g., facility, part of a facility, collection of facilities, or transportation within the identified NES) at a level amenable to further analysis.
- Target identification and categorization. Target identification is conducted by systematically examining the NES for the roles of the materials, equipment, and processes in each category. Potential targets of PR are nuclear materials, equipment, and environment processes that should be protected from the threat of diversion or malicious use. Targets of PP are nuclear materials, equipment, and information that must be protected from the threat of theft and sabotage. For additional analysis, targets are categorized into representative or border sets.
- Pathway identification and refinement. Pathways are potential sequences of events and actions by a malicious agent to achieve his objectives. Each path toward an individual target is divided into systematic segments to be analyzed. Then, the paths are connected to the entire segment path to be analyzed in detail.

- Estimation of measures. The results of the system response are expressed in terms of the high-level measures for PR&PP: i.e., proliferation technical difficulty, proliferation cost, proliferation time, fissile material type, detection probability, detection resource efficiency for PR, probability of adversary success, consequences, and physical protection resources for PP.

*2.3 Outcomes*

To determine the outcomes of the system response to a threat, analysts compare pathways and assess the system to integrate findings and interpret results. The analysts first identify the most vulnerable pathways and the measures associated with them and then integrate the findings of the analysis and interpret the results to assess the NES. The presentation of system assessment results is central to the effective use of information generated by a PR&PP evaluation and must support decision-making by three basic user types: system designers, policymakers, and external stakeholders.

## 3. Application of PR&PP Evaluation Methodology

Evaluating PR&PP for a particular NES requires a mix of expertise in management, organization, and technical skills. These must be effectively integrated to develop a thorough, defensible, and understandable evaluation. The process is implemented through nine specific tasks organized into four main activities:

- Defining the work (blue)
- Managing the process (green)
- Performing the work (yellow)
- Reporting the work (orange).

Each of the steps is primarily associated with one of these activities, although some level of management is associated with each step; reporting cannot all be done at the end, but draft material must be generated as the tasks progress. In addition, steps of the process are sometimes repeated or paired with each other. The nine steps of the process are illustrated in the figure below.

## 4. Conclusions

Proliferation resistance and physical protection (PR&PP), which is required for the security of nuclear facilities and has recently caught the attention of the international community, is a mandatory design requirement for generation IV NESs. As the Korea Atomic Energy Research Institute (KAERI) has been developing an SFR fuel cycle with pyroprocessing as part of its nuclear energy R&D since the late 1990s, the concept of PR&PP should be incorporated at the process development and design stage in order to minimize later changes in facility design and prevent subsequent economic loss. The PR&PP evaluation methodology developed by the PRPPWG provides a framework that answers a wide variety of security-related questions for the SFR fuel cycle with pyroprocessing and optimizes the associated systems to enhance their ability to withstand the threats of proliferation, theft, and sabotage.

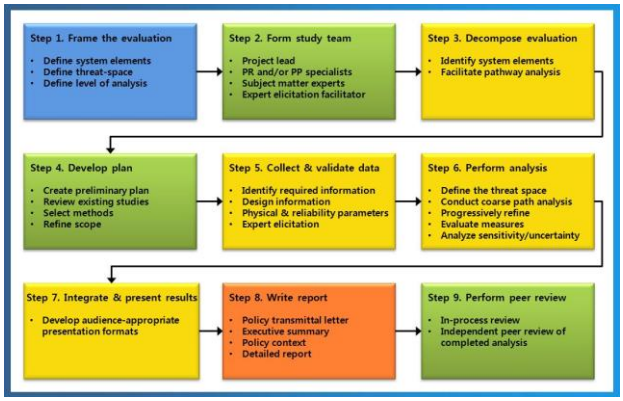


Fig.2. Steps in the PR&PP evaluation process.

## REFERENCES

[1] A Technical Roadmap for Generation IV Nuclear Energy Systems, U.S. DOE Nuclear Energy Research Advisory Committee and the Generation IV International Forum, December 2002.
[2] Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy Systems, Rev. 6, The Proliferation Resistance and Physical Protection Evaluation Methodology Expert Group of the Generation IV International Forum, September 15, 2011.