APPLICATION OF INPRO METHODOLOGY TO FAST REACTORS AND ASSOCIATED FUEL CYCLES

INPRO is the International Project on Innovative Nuclear Reactors and Fuel Cycles

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INTRODUCTION:

Fast reactors and associated fuel cycle facilities present a different proliferation concern than traditional nuclear power plants; these facilities may have nuclear material and technologies that are more attractive to proliferators. The International Project on Innovative Research Reactors and Fuel Cycles (INPRO) developed a methodology for assessing the sustainability of a State's nuclear energy systems. One of the areas of assessment is in proliferation resistance. The proliferation resistance assessment has five key requirement areas: (1) State's commitments including legal framework and institutional arrangements, (2) attractiveness of nuclear material and technologies available in the State, (3) effective and efficient implementation of international safeguards, (4) application of multiple deterrence features and measures to deter diversion, and (5) optimization of proliferation resistance that is effective and efficient for operators and approved by the State. Using the INPRO methodology for a proliferation resistance assessment provides a graded approach to address proliferation concerns of fast reactors and associated fuel cycles.

1. OVERVIEW

On 16 July 1945 the world witnessed the first nuclear explosion. World War II saw the first and only use of nuclear weapons. The devastation of these weapons made the world aware of the desire to pursue nuclear non-proliferation. In 1953 the US president addressed the United Nations General Assembly regarding the creation of an international agency for the peaceful use of atomic energy. The International Atomic Energy Agency (IAEA) was created in 1957. The Treaty on the Non-proliferation of Nuclear Weapons (NPT) was signed in 1968, came into force in 1970, and has 191 States Parties, the world's most widely adhered to treaty. [1]

The NPT declared the five states with nuclear weapons at the time of signing; these are China, France, Russian Federation, United Kingdom and United States. There are three main pillars to the NPT which each State Party undertakes.

1) To "co-operate in facilitating the application of International Atomic Energy Agency safeguards on peaceful nuclear activities" [1].

[a] The views expressed in this paper are those of the authors and do not necessarily reflect the official policy of the U.S. Department of State or the United States Government.

2) Affirm the “benefits of peaceful applications of nuclear technology, … should be available for peaceful purposes to all Parties to the Treaty” [1].

3) To “achieve at the earliest possible date the cessation of the nuclear arms race and to undertake effective measures in the direction of nuclear disarmament” [1].

See Figure 1. The IAEA oversees the NPT and through its safeguards activities verifies that nuclear material and equipment remains in peaceful use and is not diverted to nuclear weapons or other nuclear explosive devices [1].

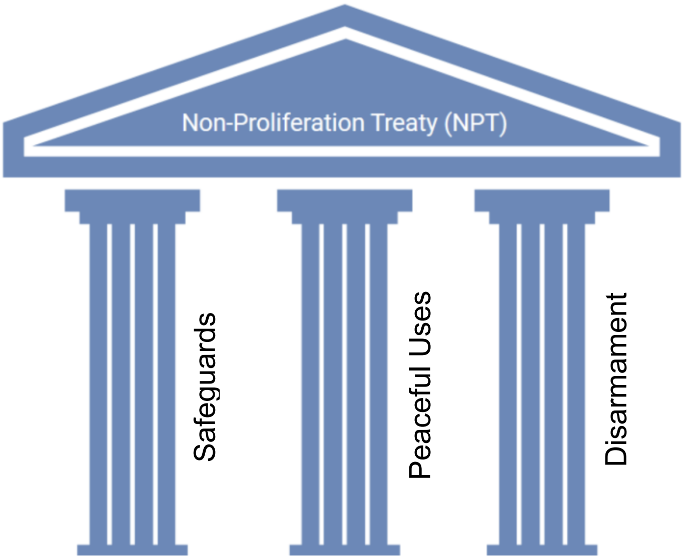

Figure 1. The three foundational pillars of the NPT. [adapted from Ref. 2]

As the global expansion of nuclear energy systems (NES) continues, misuse of nuclear technology for non-peaceful purposes remains a critical concern. While NES are developed to support civilian energy needs, their inherently dual-use nature means that components, materials, and knowledge can potentially be misused or diverted to support a nuclear weapons program. Therefore, proliferation remains a concern. There is a desire to develop new NES, such as those using fast reactors, that are more resistant to proliferation.

The IAEA publication on Proliferation Resistance Fundamentals defines proliferation resistance (PR) as “that characteristic of a nuclear energy system that impedes the diversion or undeclared production of nuclear material, or misuse of technology, by States in order to acquire nuclear weapons or other nuclear explosive devices. And the “degree of proliferation resistance results from a combination of, *inter alia,* technical design features, operational modalities, institutional arrangements, and safeguards measures” [3]. This definition is also accepted by the Generation IV International Forum’s Proliferation Resistance and Physical Protection Working Group (GIF PRPPWG) [4]. PR refers to the ability of a NES to deter or impede the diversion of nuclear material or the misuse of technology by States for the development of nuclear weapons or other nuclear explosive devices (NEDs). Therefore, a characteristic of a NES should make it technically and institutionally difficult for a State to repurpose nuclear assets from peaceful purposes to a nuclear weapons program. This resistance is achieved through a combination of intrinsic design features, extrinsic measures, operational procedures, institutional controls, and safeguards measures.

In the case of proliferation, the **Proliferator** “is a State seeking to acquire a nuclear weapon or other nuclear explosive device, which requires a sufficient mass of nuclear material, access to nuclear technologies, specialized nuclear skills and knowledge, and time to be successful.” [5] When the threat is from a non-state actor trying to acquire nuclear material, it is a security concern, which also includes sabotage of nuclear facilities and nuclear material in transport. To be successful in the pursuit of a nuclear weapon a proliferator needs nuclear material, technologies, knowledge and time.

The intrinsic features of an NES are its technical elements or physical design characteristics and features. These features include “facilities, processes, and equipment that make it difficult to gain access to nuclear material or misuse”. [6] Extrinsic measures, are those commitments, obligations and policies in a State relating nuclear non-proliferation. These measures include “bilateral agreements between exporting and importing States; commercial, legal or institutional arrangements that control access to nuclear material and nuclear energy systems; verification activities (including IAEA, regional, bilateral and national); and arrangements to address violations of nuclear non-proliferation undertakings.” [6]

Traditional fuel cycles based on low-enriched uranium (LEU) generally present lower proliferation concerns. However, innovative NES designs, such as those employing high-assay low-enriched uranium (HALEU) or incorporating fast reactor technologies, often involve materials or configurations that could pose a higher proliferation concern. These emerging technologies necessitate dedicated PR assessments to ensure that advancements in reactor design do not compromise non-proliferation objectives.

Several international initiatives, including INPRO, the Generation IV International Forum (GIF) PR&PP Working Group [7], and national programs like the U.S. Proliferation Resistance Optimization initiative (PRO-X) [8], contribute to the development of methodologies for evaluating and enhancing PR. While various assessment tools exist such as SAPRA (France) [9] and GIF PR&PP [4], the INPRO Methodology emphasizes long-term sustainability, technological gap identification, and the ability of NESs to integrate future improvements in safeguards and security. [10]

Notably, PR differs from other threats in that it addresses deliberate, hostile actions by States, rather than accidental or systemic failures. Therefore, PR must consider not only technical parameters but also institutional and international commitments and obligations such as safeguards which is a requirement of the NPT.

2. INPRO METHODOLOGY FOR NUCLEAR ENERGY SYSTEM ASSESSMENT

In 2001 the International Atomic Energy Agency (IAEA) launched the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) to ensure that nuclear energy is available in a sustainable manner to contribute to the energy needs in the 21st century and beyond. INPRO supports members to achieve desired innovations in nuclear reactors and fuel cycles that are economically competitive, have inherent safety features, minimize the risk of proliferation and minimize environmental impacts. A primary objective is to ensure sustainability of nuclear energy systems including fast reactors and associated fuel cycles.

2.1. Concept of Sustainable Energy Development

To support member States in achieving sustainable nuclear energy systems INPRO developed the INPRO methodology for assessing the sustainability of nuclear energy systems. The developers of the methodology used the United Nations (UN) concept of sustainable energy development [11], which requires the balancing of economic growth, environmental protection, societal equity, and institutional frameworks. The INPRO methodology is a structured approach, developed through the collaboration of many international experts, for self-assessing the sustainability of nuclear energy systems. There are six areas for the assessment: economics, safety, environmental impacts, waste management, infrastructure, and proliferation resistance. See Figure 2. The methodology is a globally recognized framework for evaluating the sustainability of nuclear energy systems (NES).

The methodology was first introduced in 2003 [12], followed by the publication of detailed assessment manuals in 2008 [13]. Since then, the methodology has undergone significant revisions, most notably between 2014 and 2025, reflecting advances in technology, feedback from users and lessons learned [14], and input from national and international experts.

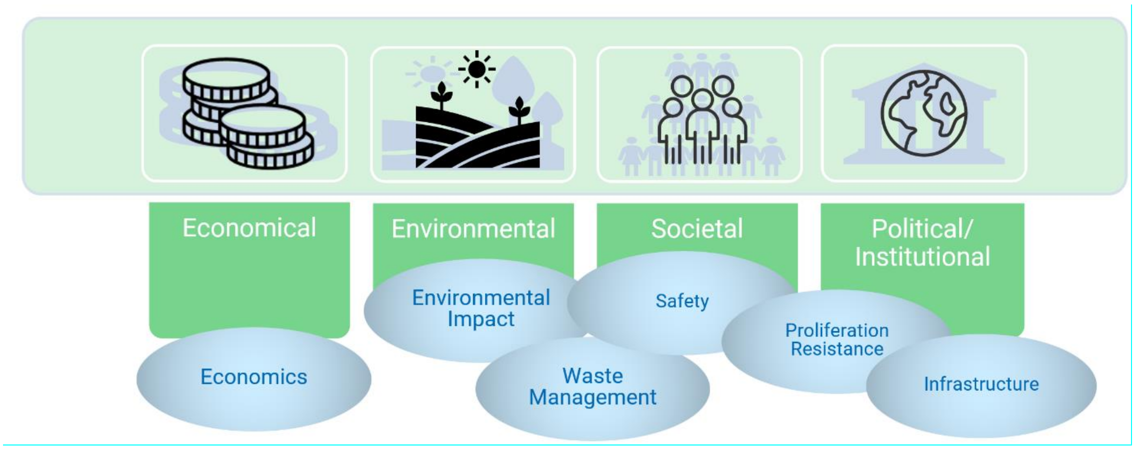

Figure 2. The United Nations pillars for sustainable energy development overlaid with the INPRO Methodology assessment areas for nuclear energy systems.

2.2. General Framework

The methodology is holistic covering all areas important for sustainability, especially in the context of public acceptance. Additionally, the methodology covers all parts of the nuclear fuel cycle and the entire lifecycle, from design through construction, operation, and decommissioning. The framework for the methodology is hierarchical. The foundation is a basic principle for each assessment area with user requirements (UR), further defined by criteria (CR) and acceptance limits (AL) to support the assessor for making an assessment; see Figure 3. When the assessor finds that criteria are not met, this identifies a gap in sustainability. To close the gap the NES may need to be redesigned. Alternatively, in the case of innovative technologies such as fast reactors and associated fuel cycles it may identify areas that need research and development (R&D). [15]

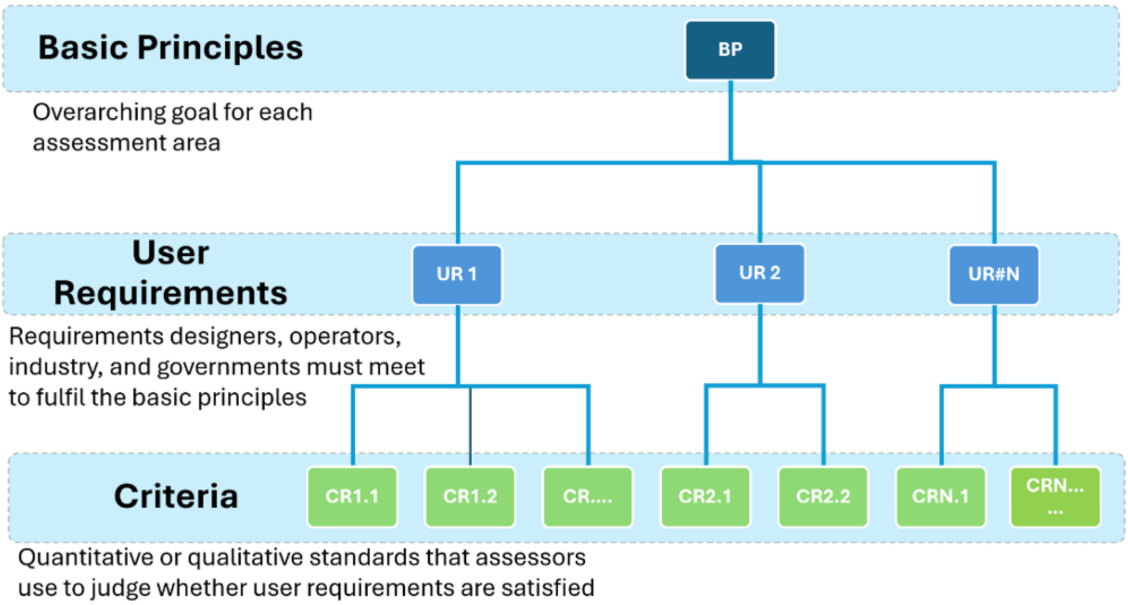

Figure 3: Relationship of basic principle (BP), user requirements (UR) and criteria (CR) in INPRO sustainability assessment. Hierarchical Structure of the Methodology [16]

2.3. Assessment Areas and Goals

The six assessment areas outlined by the INPRO methodology, as mentioned earlier, collectively support a comprehensive sustainability evaluation and reflect broader societal concerns. Each area has specific sustainability objectives, see Figure 4.

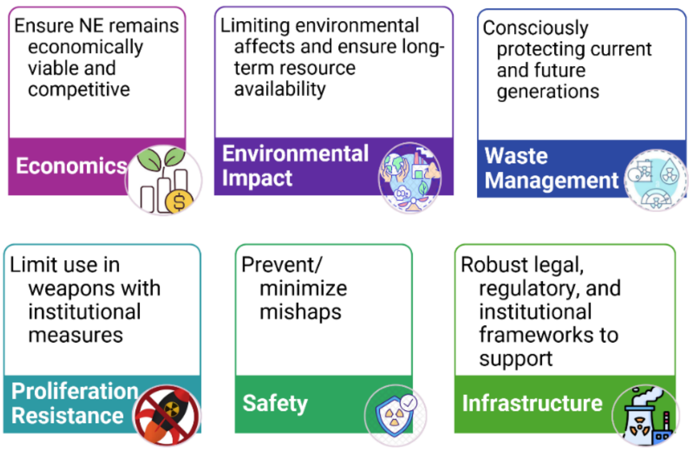

Figure 4: The INPRO six key assessments areas and the respective goals for each. [17]

The Basic Principle is "Proliferation resistance intrinsic features and extrinsic measures should be implemented throughout the life cycle of a nuclear energy system (NES) to help ensure that the NES will continue to be an unattractive means to acquire nuclear material for a nuclear weapon or other nuclear explosive device; both intrinsic features and extrinsic measures are essential, and neither can be considered sufficient by itself [18]." Intrinsic features are "those features which result from the technical design of nuclear energy systems, including those that facilitate the implementation of extrinsic measures [19]." Intrinsic features relate to physical design features and support implementation of IAEA safeguards. Extrinsic measures are related "to State's commitments, obligations, and policies regarding nuclear non-proliferation; bilateral agreements between exporting and importing States; commercial, legal or institutional arrangements that control access to nuclear material and nuclear energy systems; verification activities (including IAEA, regional, bilateral and national); and arrangements to address violations of nuclear non-proliferation undertakings [19]." Hence, extrinsic measures include treaties, agreements, the application of IAEA safeguards, security forces and equipment to impede proliferation.

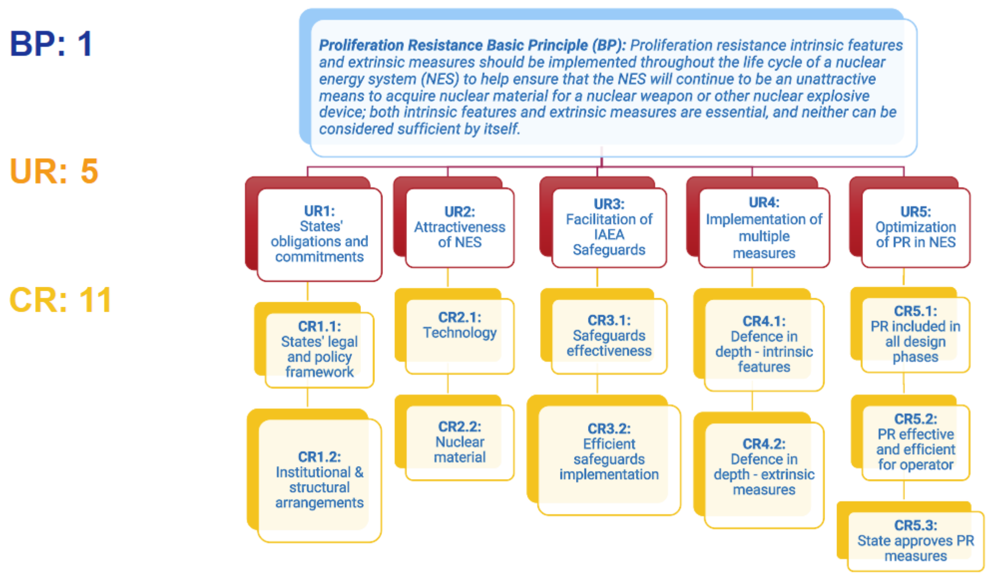

Figure 5: The INPRO methodology in proliferation resistance, showing relationship between (BP), (UR) and (CR) [20]

The INPRO Methodology for proliferation resistance is used to evaluate nuclear materials and facilities that a State has reported to the IAEA. This self-assessment examines the risk of a State (acting as a proliferator) diverting nuclear materials or misusing facilities and technology to develop nuclear weapons or other nuclear explosive devices. For a State to successfully engage in proliferation, four key conditions must be met: (1) a quantity of nuclear material, (2) access to technology, (3) specialized knowledge and skills, and (4) time [21, 22]. The INPRO methodology for proliferation resistance considers all four requirements.

The INPRO assessments focus solely on declared NESs operating within legal frameworks, and do not address undeclared activities, illicit procurement, or intent.

For INPRO, enhancing PR is not about assigning scores or rankings but about identifying design vulnerabilities and supporting the development of robust, sustainable NES architectures capable of withstanding misuse over operational lifespans approaching a century.

3. APPLYING INPRO METHODOLOGY TO FAST REACTORS AND ASSOCIATED FUEL CYCLE FACILITIES

Fast reactors (FRs), particularly those operating within closed fuel cycles, pose unique proliferation challenges primarily due to their integration with spent fuel reprocessing and plutonium separation technologies. Unlike conventional once-through fuel cycles used in light-water reactors, closed fuel cycles rely on reprocessing to recover fissile materials, uranium and plutonium for recycling as reactor fuel. This process inherently involves handling and separating weapons-usable materials, raising significant proliferation concerns, on the other hand new reactors can consider intrinsic features and extrinsic measures from early design phases.

3.1. UR1: State's obligations and commitments

The first user requirement (UR1) states:

> **"UR1:** *State's obligations, commitments, and policies regarding non-proliferation and their implementation should be adequate to achieve the objectives of the international nuclear non-proliferation regime." [5]*

This assessment regards the legal and policy framework and assesses that it is in accordance with international obligations and consistent with international commitments, standards, and best practices, and ensures and facilitates effective IAEA safeguards. This is the first criteria. States can check the status of national implementation at the UN 1540 Committee website, for an update on their international commitments. [23]

Additionally, the second criteria evaluates the institutional and structural arrangements that support a State's commitments regarding non-proliferation and facilitates the implementation of IAEA safeguards. All states pursuing fast reactor technologies need to have their safeguards agreement in place including reporting the pursuit of fast reactor technology.

The proliferation concern for fast reactors extends beyond technical safeguards to encompass geopolitical dynamics. Access to advanced fuel cycle technologies is intertwined with national security priorities and diplomatic relations. Suspicion towards fast reactor programs can hinder international cooperation [24], complicate supply chain development, and exacerbate geopolitical tensions. Conversely, denial of access risks technological marginalization, potentially driving illicit proliferation pathways.

3.2. UR2: Attractiveness of nuclear energy systems

The second user requirement (UR2) states:

> **"UR2:** *The attractiveness of nuclear technology and nuclear material in an NES should be low for acquiring a nuclear weapon or other nuclear explosive device." [5]*

The first criteria examines the attractiveness of the technologies in a State to a proliferator. The evaluation scale for the attractiveness to a proliferator is from very high, high, moderate, low and very low. This scale covers both technologies and nuclear material. When the technologies do not exist in a State the attractiveness level is very low.

Highly attractive technologies for a proliferator are the capability to reprocess irradiated fuel and separate isotopes, enrich uranium, and fabrication of metal fuels. Reprocessing spent nuclear fuel from fast reactors involves sophisticated chemical processes that isolate uranium and plutonium from highly radioactive fission products. The quantities and accessibility of separated uranium or plutonium is highly attractive to a proliferator. [25]

Fast reactors typically employ metallic or mixed oxide fuels that facilitate fuel recycling but also necessitate specialized reprocessing technologies tailored to handle these fuel forms. The deployment of such tailored reprocessing increases technical and security challenges, as novel chemical processes and facilities require rigorous verification protocols, to assure they are not being misused.

3.3. UR3: Facilitation of IAEA safeguards

The third user requirement (UR3) states:

> **"UR3:** *The NES should have intrinsic features and implement extrinsic measures that readily facilitate IAEA safeguards." [5]*

All non-nuclear weapons States, under their safeguards agreement, have an obligation to declare their interest to the IAEA in deploying fast reactors and associated fuel cycles. The IAEA develops the safeguards approach based on the technology, facilities, and nuclear material. Safeguarding fast reactors and associated fuel cycles is technically more challenging than traditional light water nuclear power plants. The fast reactor facilities may contain separated plutonium or uranium in reprocessing facilities, which require stringent physical security, material accountancy, and safeguard measures to prevent diversion or misuse. [25]

Existing non-proliferation frameworks, principally managed by the International Atomic Energy Agency (IAEA), face limitations in adequately addressing the unique characteristics of fast reactor fuel cycles. The historical linkage of separated uranium or plutonium to nuclear weapons programs generates political sensitivities that complicate the international acceptance of closed fuel cycles [24]. Countries expanding fast reactor capabilities without established reprocessing infrastructure pose additional verification and enforcement challenges.

Harmonizing international safeguards for advanced fuel cycle facilities requires developing strengthened verification technologies, multilateral fuel cycle governance models, and potentially establishing multinational fuel cycle centres under strict control to reduce proliferation risk. International safeguards must be robust and adaptive to these evolving technologies to ensure effective monitoring and verification.

Comprehensive nuclear material control and accounting, and transparency are essential. Incorporating safeguards by design early can help with reduced costs and improve efficiency and effectiveness.

3.4. UR4: Implementation of multiple measures

The fourth user requirement (UR4) states:

> **"UR4:** *The NES should incorporate multiple proliferation resistance intrinsic features and extrinsic measures." [5]*

This UR goes together with UR2. When an NES has more attractive technologies or nuclear material, then designers need to consider incorporating additional intrinsic features and extrinsic measure into the NES to ensure that it is more difficult to misuse facilities or divert nuclear material to nonpeaceful purposes. UR4 "necessitates the analysis of technically plausible diversion pathways, which are those paths suitable from a technical point of view for a State to acquire nuclear material for a nuclear weapon or other nuclear explosive device." [26] This analysis supports the implementation of multiple design features, which are complementary, redundant, and diverse to cover the diversion and misuse scenarios.

3.5. UR5: Optimization of PR in NES design

The fifth user requirement (UR5) states:

> **"UR5:** *The combination of intrinsic features and extrinsic measures, compatible with other design considerations, should be optimized (in the design/engineering phases) to provide effective and efficient proliferation resistance, which is effective for the operator and acceptable to the State." [5]*

This UR requires the PR be considered throughout all the design phases of the NES, and throughout its lifecycle. Furthermore, it regards the consideration of PR intrinsic features that are effective and efficient for the operator of the NES. The assessor must also examine that the facilities can meet their obligations in nuclear material accounting and reporting. The last criteria mandates that the State approve the PR measures and features.

The designer of the NES should consider the unique features of fast reactors and their associated fuel cycles in regard to proliferation resistance. Some of the features are the selection of nuclear fuels, the management of fuel (storage fresh fuel and irradiated fuel on site), and the incorporation of monitoring and surveillance systems to facilitate safeguards. [26]

3.6. INPRO Assessment in proliferation resistance

Proliferation resistance for fast reactors (FRs) and their associated fuel cycles is crucial due to the unique characteristics of these systems. Fast reactors typically operate with closed fuel cycles, involving complex reprocessing technologies and separation of plutonium or uranium, which raises concerns about the potential for nuclear weapons proliferation. These challenges necessitate the application of the INPRO methodology, which integrates both intrinsic and extrinsic measures to evaluate and improve the proliferation resistance of fast reactors and associated fuel cycles. The key to managing proliferation is a comprehensive combination of design features, operational protocols, and institutional safeguards.

The INPRO methodology supports innovative NES, including fast reactors and associated fuel cycles. The methodology in proliferation resistance assists in identifying gaps in sustainability which could be addressed during design phases. Additionally, gaps may identify areas that need research and development to close. Fast reactors and associated fuel cycles are more attractive to proliferators. These facilities may have fuel cycles with large quantities of uranium and plutonium, thus requiring effective safeguards measures. Furthermore, closed fuel cycles with reprocessing and recycling of fuel are more complicated for nuclear material accountancy, and bulk handling of nuclear material may require unique containment and surveillance measures.

4. SUMMARY

Fast reactors and their associated closed fuel cycles introduce significant proliferation risks due to the handling and separation of plutonium and other fissile materials. While reactor design and fuel form innovations can enhance proliferation resistance, these measures do not mitigate the intrinsic risks of separated materials [24]. Management of effective proliferation concerns demands advanced, adaptive international safeguards, strengthened regulatory frameworks, rigorous material security, and geopolitical diplomacy. The successful global deployment of fast reactors hinges on addressing these proliferation challenges comprehensively throughout the lifetime of these facilities.

ACKNOWLEDGEMENTS

This work's funding was through INPRO Member States extrabudgetary contributions to the INPRO Section. These contributions support INPRO activities and are implemented by INPRO Members together with and assisted by the INPRO Section staff and are subject to availability of staff and budgetary resources.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The IAEA and the Non-Proliferation Treaty, https://www.iaea.org/topics/non-proliferation-treaty (accessed 21 July 2025).

[2] Rebolledo, V. G., and MULAS, R., EU Non-proliferation and Disarmament, Unit 5, Nuclear Weapons II: Non-Proliferation, Disarmament and Peaceful Uses, here: https://nonproliferation-elearning.eu/learningunits/nuclear-weapons-II/course.pdf (accessed 21 July 2025).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Proliferation Resistance Fundamentals for Future Nuclear Energy Systems, Safeguards Technical Reports No. STR-332, IAEA, Vienna (2002).

[4] GENERATION IV INTERNATIONAL FORUM (GIF) PROLIFERATION RESISTANCE AND PHYSICAL PROTECTION WORKING GROUP (PRPPWG), Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy Systems, Rev. 5, Report GIF/PRPPWG/2006/005, (2006).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Proliferation Resistance, IAEA Nuclear Energy Series No. NG-T-3.26, IAEA, Vienna (to be published).

[6] SCHERER, C., ARDHAMMAR, M., BOYER, B, et al., Updating and Enhancing the INPRO Proliferation Resistance Methodology for Better Sustainability Assessments, Proceedings of the INMM & ESARDA Joint Annual Meeting, 21-25 May 2023, Vienna, Austria.

[7] CIPITI, B., et al., Proliferation Resistance and Physical Protection White Papers of the Six Gif Generation IV Nuclear Energy Systems and Crosscutting Topics: 2021-2022 Update, Sandia National Laboratories, SAND2022-11784C, Albuquerque, USA, 2022.

[8] U.S. DEPARTMENT OF ENERGY, Proliferation Resistance Optimization (PRO-X), https://www.energy.gov/nnsa/proliferation-resistance-optimization-pro-x (accessed 21 July 2025).

[9] GRENECHE, D., A Practical Tool to Assess the Proliferation Resistance of Nuclear Systems, the SAPRA Methodology, ESARDA Bulletin, No. 39, pp. 41-49 (2008).

[10] SCHERER, C., BOYER, B., ILHAN, G., WANG, Y, DEWES, J., and POIRIER, S., Assessing Proliferation Resistance of Research Reactor Facilities Using INPRO Methodology, European Research Reactor Conference, Antwerp, Belgium, April 2023.

[11] BRUNDTLAND, G.H., Our Common Future: Report of the World Commission on Environment and Development, Geneva, UN-Dokument A/42/427 (1987).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Guidance for the Evaluation of Innovative Nuclear Reactors and Fuel Cycles Report of Phase 1A of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), IAEA-TECDOC-1362, IAEA, Vienna (2003)

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Guidance for the Application of an Assessment Methodology for Innovative Nuclear Energy Systems, IAEA-TECDOC-1575, Rev. 1, IAEA, Vienna (2008).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Lessons Learned from Nuclear Energy System Assessments (NESA) Using the INPRO Methodology. A Report of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), IAEA-TECDOC-1636, IAEA, Vienna (2009).

[15] SCHERER, C., ARDHAMMAR, M., BOYER, B., LEE, J.-S., POIRIER, S., ADAMS, S., BATHKE, C., CHIRAYATH, S., COJAZZI, G., RENDA, G., REYES, G., VAN DER ENDE, B., "Updating and enhancing the INPRO proliferation resistance methodology for better sustainability assessments", Proceedings of the INMM & ESARDA Joint Annual Meeting (Proc. Int. Conf. Vienna, 2023), INMM & ESARDA, Vienna (2023).

[16] INPRO METHODOLOGY - INPRO Wiki. Available at: http://inpro-dev.westeurope.cloudapp.azure.com/wiki/index.php/INPRO_methodology (Accessed: 09 July 2025).

[17] INPRO methodology - INPRO Wiki. Available at: http://inpro-dev.westeurope.cloudapp.azure.com/wiki/index.php/INPRO_methodology (Accessed: 09 July 2025).

[18] INTERNATIONAL ATOMIC ENERGY AGENCY, INPRO Methodology for a Sustainability Assessment of a Nuclear Energy System: Proliferation Resistance, Vienna (to be published).

[19] INTERNATIONAL ATOMIC ENERGY AGENCY, Technical Features to Enhance Proliferation Resistance of Nuclear Energy Systems, IAEA Nuclear Energy Series No. NF-T-4.5, Vienna (2010).

[20] SCHERER, C., "INPRO Methodology: Proliferation Resistance, presented at Joint ICTP-IAEA School on Nuclear Energy Strategic Planning and Application of INPRO Methodology for Sustainability Assessment, 26-30 September 2022, Trieste, Italy.

[21] INTERNATIONAL ATOMIC ENERGY AGENCY, Technical Features to Enhance Proliferation Resistance of Nuclear Energy Systems, IAEA Nuclear Energy Series No. NF-T-4.5, Vienna (2010).

[22] GENERATION IV INTERNATIONAL FORUM, Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy Systems, Rev. 6, GIF/PRPPWG/2011/003, (2011).

[23] UNITED NATIONS, 1540 Committee, National Reports, here: https://www.un.org/en/sc/1540/national-implementation/national-reports.shtml (accessed 21 July 2025).

[24] SUSTAINABILITY DIRECTORY, "What challenges does fast reactor deployment face ?", Energy Sustainability-Directory (2023), https://energy.sustainability-directory.com/question/what-challenges-does-fast-reactor-deployment-face/.

[25] GRENECHE, D. (2009) 'Proliferation issues related to the deployment of Fast Neutron Reactors (FNRs)'. Challenges and opportunities (International conference on fast reactors and related fuel cycles (FR09)), p. [30 p.].

[26] SCHERER, C., BOYER, B., ILHAN, G., WANG, Y., DEWES, J. and POIRIER, S., Assessing Proliferation Resistance of Research Reactor Facilities Using INPRO Methodology, IAEA European Research Reactor Conference, 16-20 April 2023, Antwerpen, Belgium.