INPRO Methodology for Proliferation Resistance of Fast Reactors and Fuel Cycles

INPRO the International Project on Innovative Nuclear Reactors and Fuel Cycles

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Outline

- Introduction to Proliferation Resistance (PR)
- Introduction to INPRO Methodology
- PR: Basic Principle and Framework
- Application to Fast Reactors and Fuel Cycles
- Brief Summary

Nuclear Non-Proliferation Treaty (NPT)

Landmark international treaty that aims to

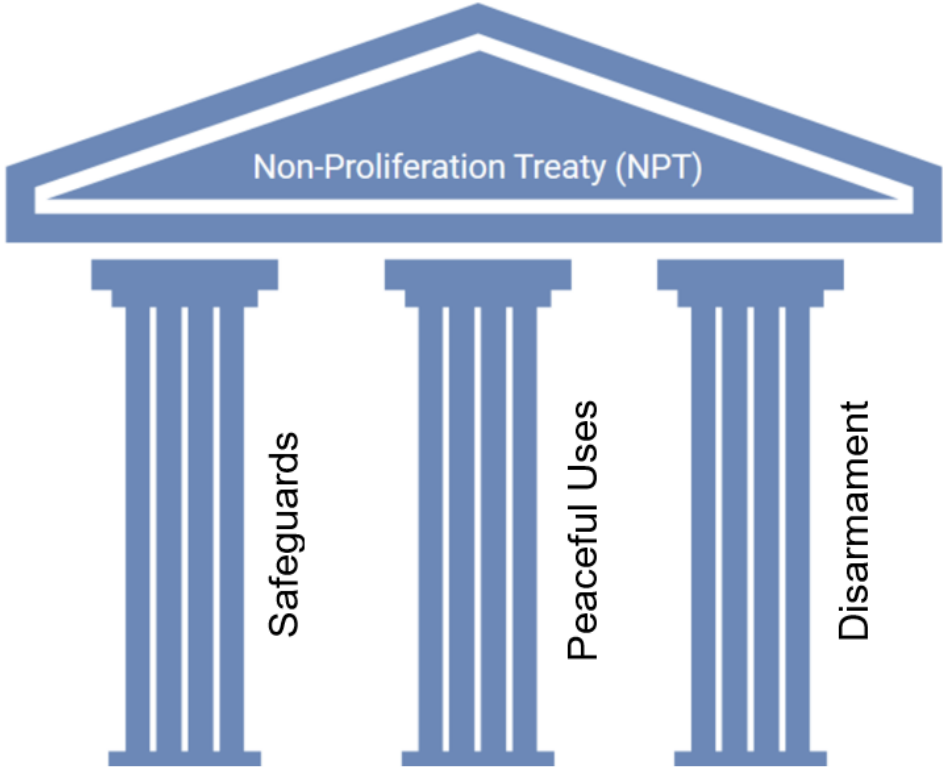
- prevent the spread of nuclear weapons and other nuclear explosive devices,
- promote cooperation in the peaceful uses of nuclear energy, and
- further the goal of nuclear disarmament

opened for signature in 1968 and entered into force in 1970

cornerstone of the global nuclear non-proliferation regime

Most widely signed treaty

3 Pillars of NPT



Non-proliferation Treaty

1. Facilitate the application of IAEA Safeguards
2. Promote peaceful use of nuclear energy
3. Move towards nuclear disarmament

Introduction – Proliferation Resistance

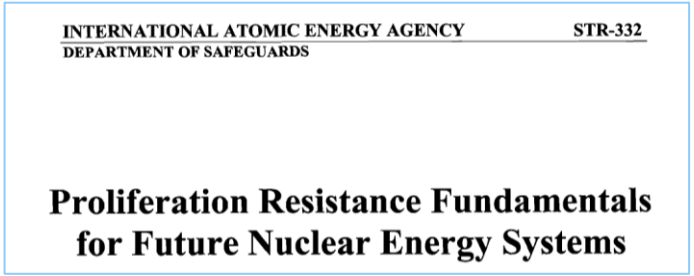
- **Proliferation Resistance is**

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.

- **Degree of Proliferation Resistance**

results from a combination of, *inter alia*, technical design features, operational modalities, institutional arrangements, and safeguards measures

2002


INTERNATIONAL ATOMIC ENERGY AGENCY STR-332
DEPARTMENT OF SAFEGUARDS

Proliferation Resistance Fundamentals for Future Nuclear Energy Systems

Proliferator

State seeking to acquire a nuclear weapon or other nuclear explosive device

Which requires

- Nuclear material

- Technology

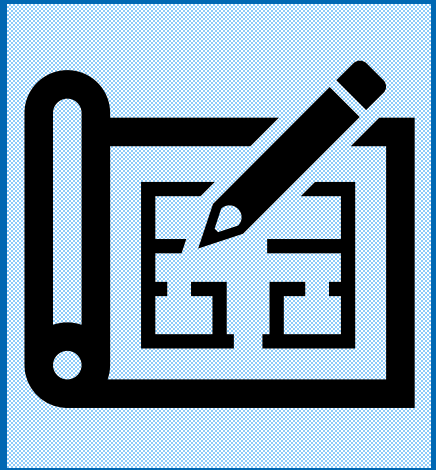
- Skills & knowledge

- Time

to be successful

Intrinsic Features

- Technical barriers or design characteristics of NFC that make it difficult to gain access to materials or misuse facilities to obtain material for nuclear weapons or other explosives
- Misuse includes replication or modification of facilities, processes and technology to support weapons development
- Includes attractiveness of nuclear material and facilities



Extrinsic Measures

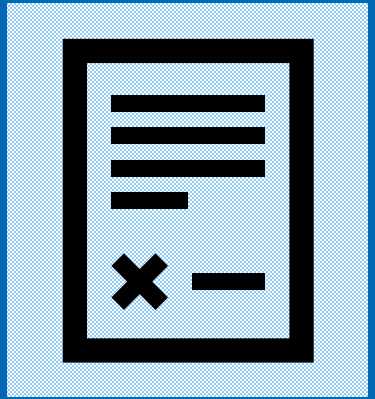
Related to State's commitments, obligations, and policies regarding nuclear non-proliferation

Bilateral agreements between export/import States

Commercial, legal or institutional arrangements that control access to nuclear material and energy systems

Verification activities

Arrangements to address violations of nuclear non-proliferation and safeguards undertakings



INPRO Methodology

For assessing the sustainability of innovative nuclear energy systems (NES)

UN Concept of Sustainable Development

“development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”*

- Concept of needs - in particular the essential needs of the world’s poor, to which overriding priority should be given
- Idea of limitations - imposed by the state of technology and social organization on the environment’s ability to meet present and future needs


Report of the World Commission on Environment and Development: Our Common Future

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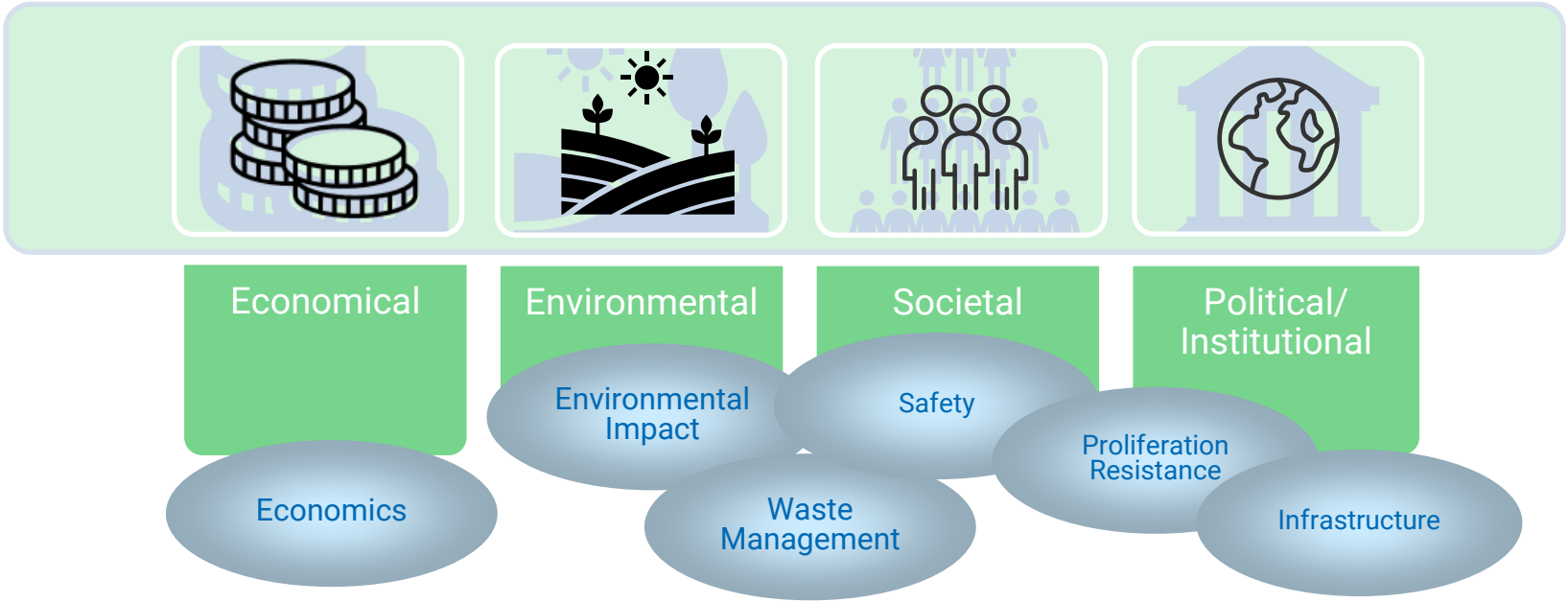
*“*Report of the World Commission on Environment and Development: **Our Common Future**”, Oxford University Press, Oxford (1987)*

UN Concept of Sustainable Energy Development



INPRO Sustainable Nuclear Energy

INPRO Methodology Key Areas

Ensure NE remains economically viable and competitive

Economics

Limiting environmental effects and ensure long-term resource availability

Environmental Impact

Consciously protecting current and future generations

Waste Management

Unattractive to a proliferator

Proliferation Resistance

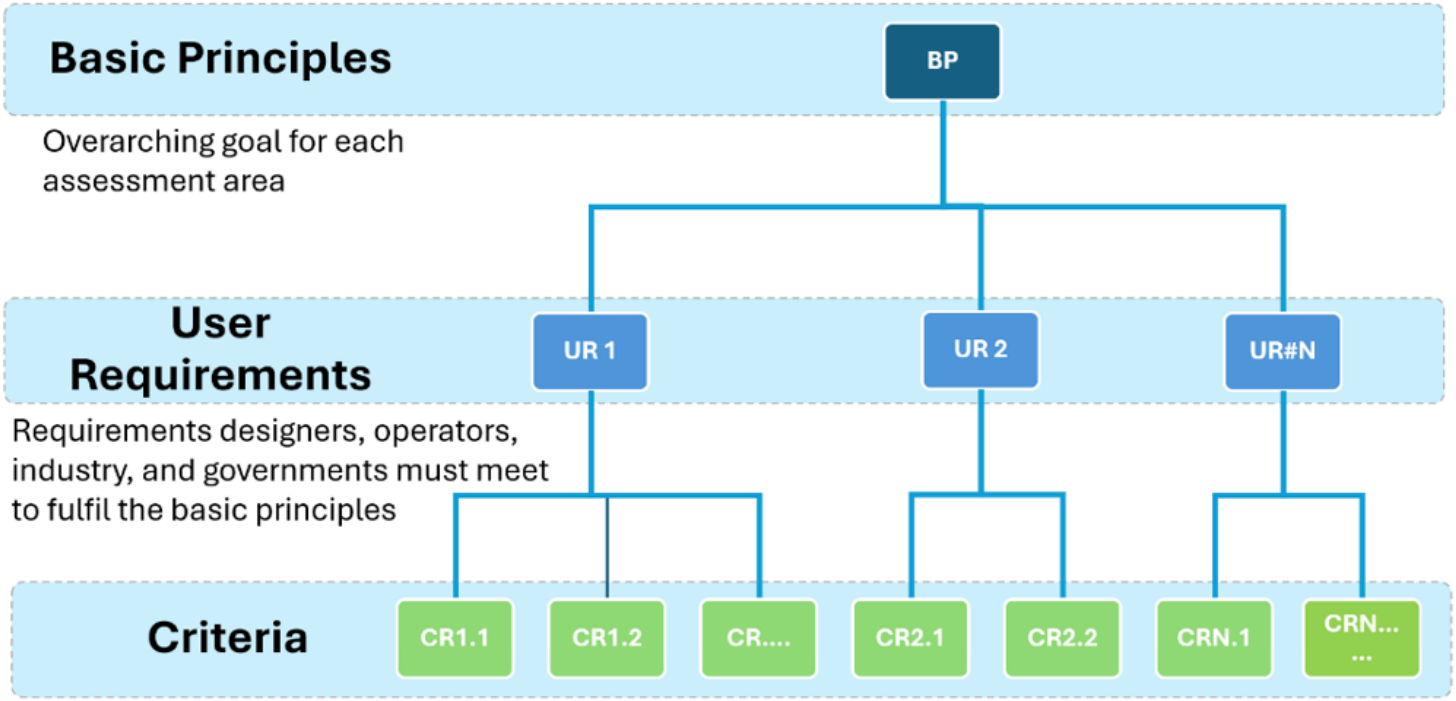
Prevent/ minimize mishaps

Safety

Robust legal, regulatory, and institutional frameworks to support

Infrastructure

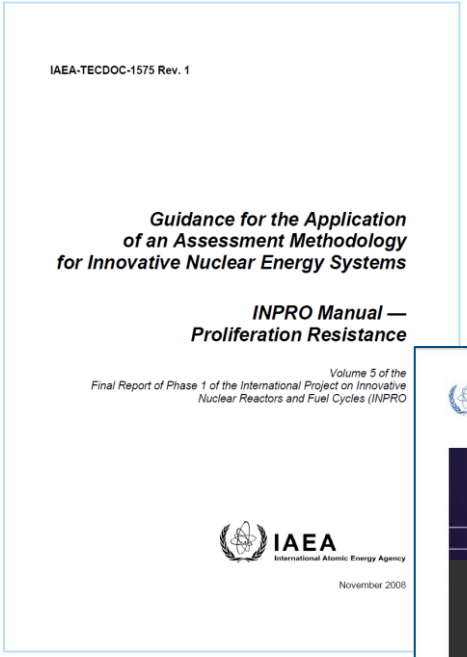
INPRO Methodology Framework



INPRO Methodology

Proliferation Resistance

- Major revision to INPRO PR Manual
- 9 Consultancy Meetings
- ~40 international experts
- Improved and streamlined assessment
- Good for comparing options
- Preprint should be ready soon!



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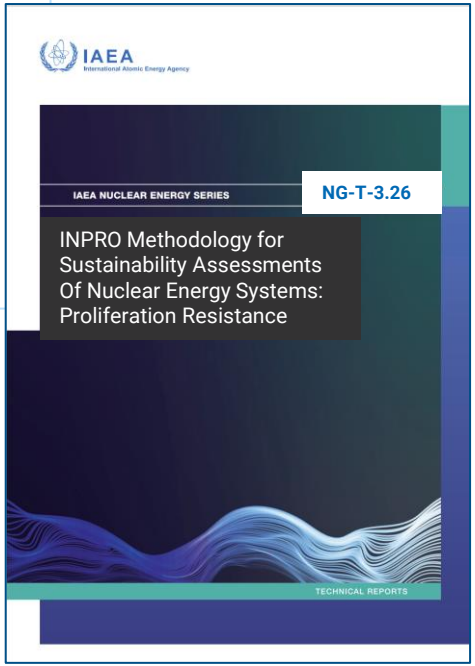


Basic Principle

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.

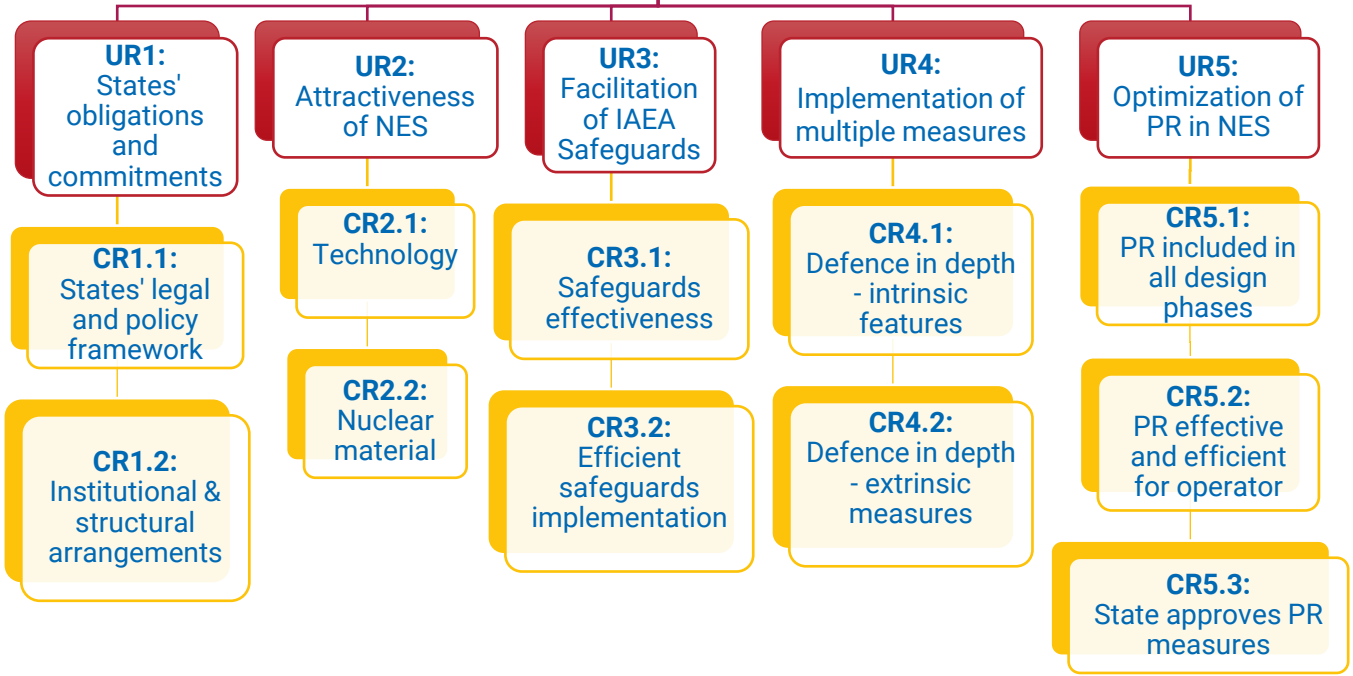
Proliferation Resistance Framework

BP: 1

UR: 5

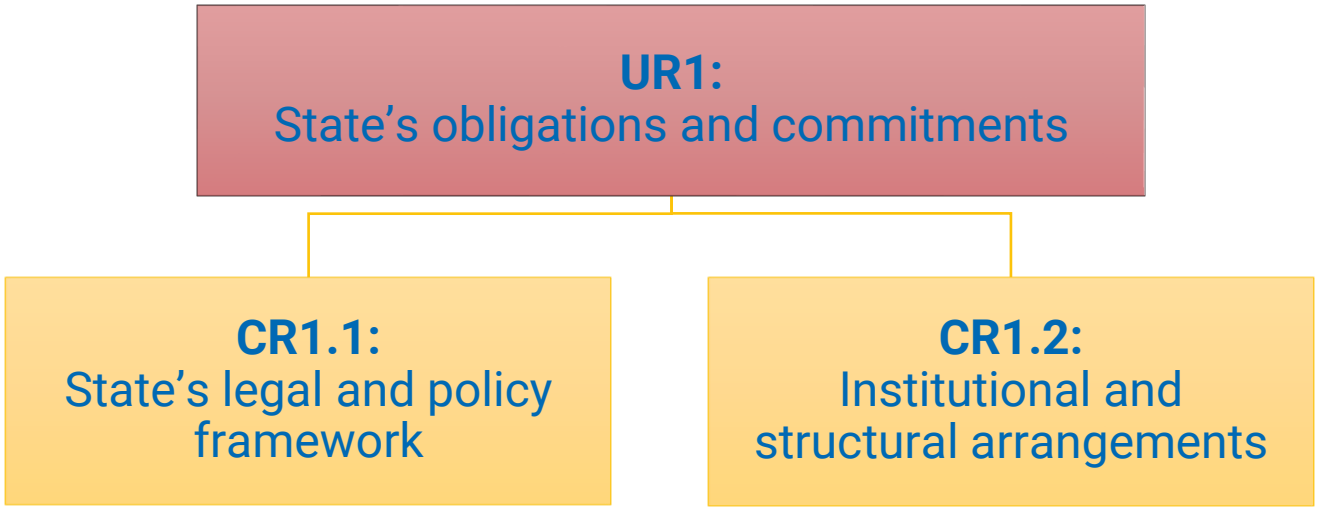
CR: 11

Proliferation Resistance Basic Principle (BP): *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.*



UR1: State's Obligations and Commitments

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.



UR1: Indicators and Acceptance Limits

UR1: State's obligations and commitments

CR1.1: State's legal and policy framework

IN1.1: State's **international obligations, commitments, and national laws** and policies regarding nuclear non-proliferation to fulfil international standards

AL1.1: Legal and policy framework established in accordance with international obligations and consistent with international commitments, standards, and best practices, and ensures/facilitates effective implementation of IAEA safeguards

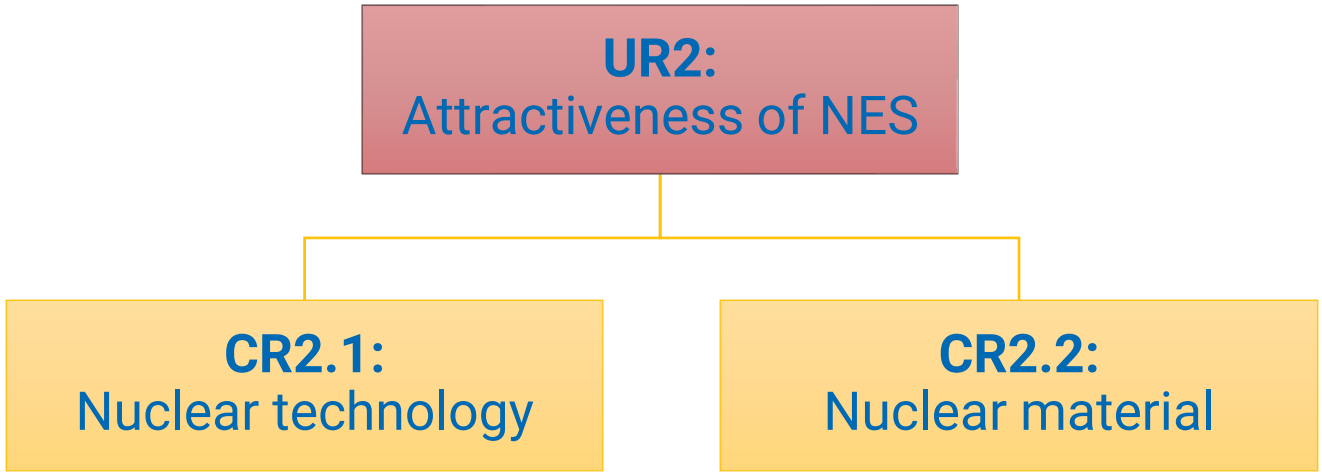
CR1.2: Institutional and structural arrangements

IN1.2: State's **institutional and structural arrangements** support proliferation resistance

AL1.2: Institutional and structural arrangements support State's commitments regarding non-proliferation and facilitate the implementation of IAEA safeguards

UR2: Attractiveness of NES

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.



Concept of Attractiveness

How attractive is the nuclear technology and material to a proliferator?

Evaluation scale is attractiveness to proliferator

Very high, High, Moderate, Low, Very low

IN2.1: Attractiveness of nuclear technology

AL2.1: The attractiveness of all technology considered in the NES and within the State is addressed

Evaluation Parameter (EP)	Evaluation Scale (Attractiveness for proliferation)				
	Very High	High	Moderate	Low	Very Low
EP2.1.1: Reprocessing (extraction of fissile material)	Yes			No	
EP2.1.2: Enriching uranium	Yes			No	
EP2.1.3: Fabricating metal fuels	Yes			No	
EP2.1.4: Fabricating Pu-bearing non-metal fuel (MOX)		Yes		No	
EP2.1.5: Fabricating UOX fuel			Yes	No	
EP2.1.6: Fabricating other fuel (nitrides, carbides, TRISO, etc.)		Yes		No	
EP2.1.7: Irradiating fertile material		Yes		No	
EP2.1.8: Conditioning of spent fuel		Yes		No	
EP2.1.9: Producing medical isotopes		Yes		No	
EP2.1.10: Remote handling (hot cells, gloveboxes)		Yes		No	
EP2.1.11: Having dual-use equipment			Yes	No	

CR2.2: Nuclear material

IN2.1: Attractiveness of nuclear material

AL2.1: The attractiveness of all nuclear material in the NES and within the State is addressed

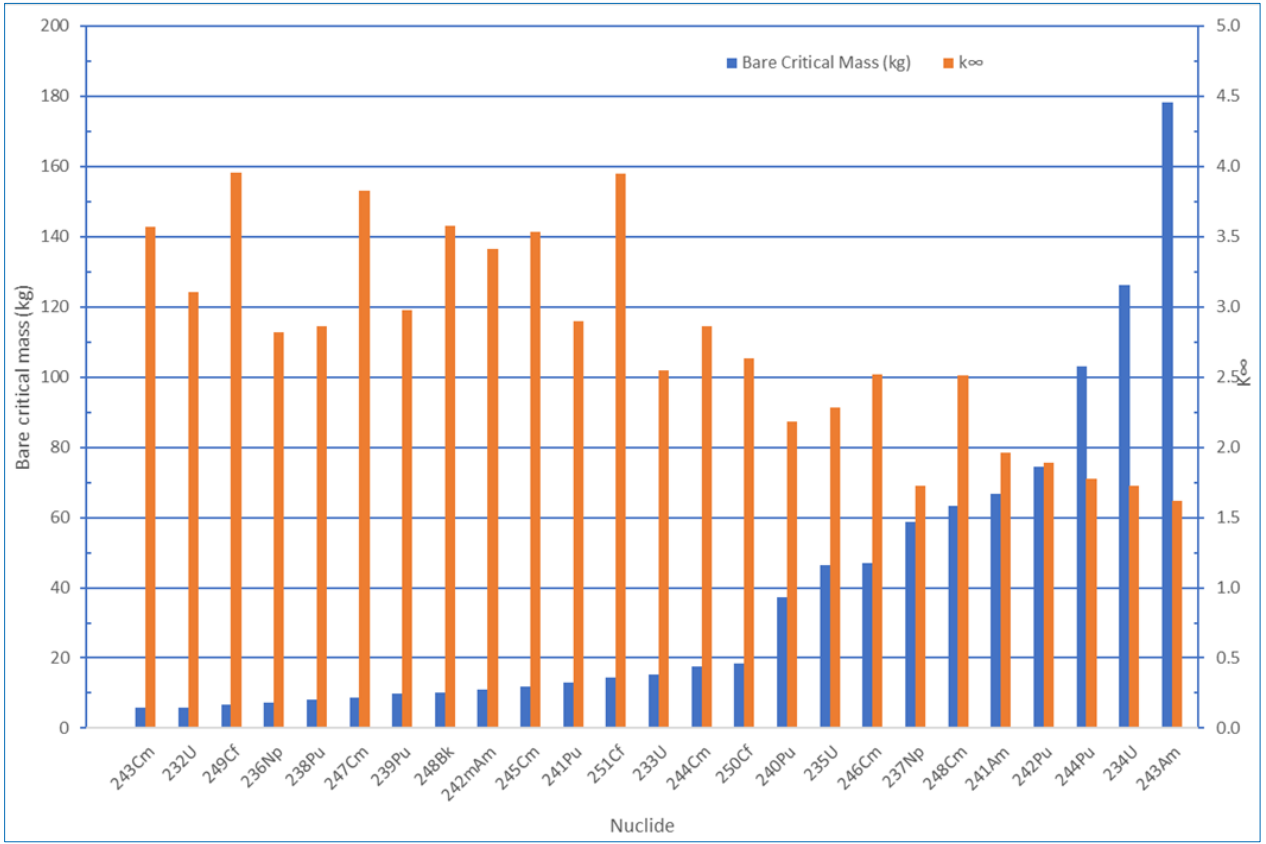
EP.2.2.1: Material type and isotopic composition
EP.2.2.2: Quantity of nuclear material
EP.2.2.3: Chemical or physical form of nuclear material

IN2.2: Attractiveness of nuclear material

AL2.2: The attractiveness of all nuclear material in the NES and within the State is addressed

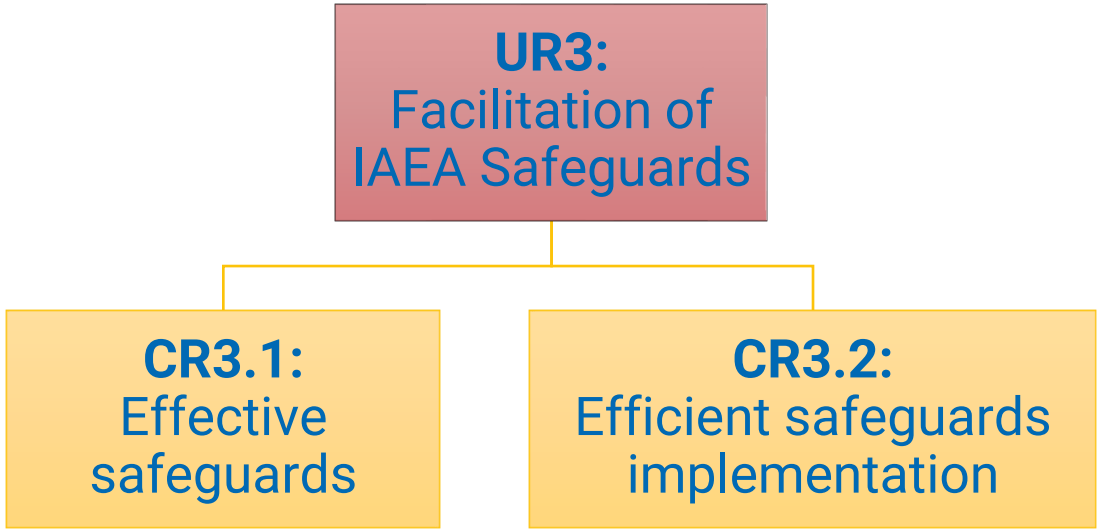
Evaluation Parameter (EP)	Evaluation Scale (Attractiveness for proliferation)				
	Very High	High	Moderate	Low	Very Low
EP.2.2.1: Material type and isotopic composition					
Direct use: Pu or $^{233}U \geq 8$ kg; $^{235}U \geq 25$ kg, $^{235}U/U \geq 20\%$)	>1 SQ (# SQs)	<1 SQ (#SQ)			
Indirect use: $^{235}U \geq 75$ kg; $^{235}U/U < 20\%$, $^{233}U/U < 12\%$; natural U≥10 t or depleted U≥20 t		>1 SQ or LEU≥5%		LEU<5%	NU or DU or Th
Other isotopes (other): bare critical mass (M)	>M	<M		<10% M	M = 0
EP.2.2.2: Quantity (number of SQs)	$\geq 10^3$	$100-<10^3$	10–<100	1–<10	<1
EP.2.2.3: Chemical or physical form	Metal	Oxide/ Solution	U Compounds	Spent Fuel	Waste

Isotopes with a bare critical mass (M)



UR3: Facilitation of IAEA Safeguards

UR3: The NES should have intrinsic features and implement extrinsic measures that readily facilitate IAEA safeguards



UR3: Indicators and Acceptance Limits

UR3: *The NES should have intrinsic features and implement extrinsic measures that readily facilitate IAEA safeguards.*

CR3.1: Effective safeguards

IN3.1: Detectable **diversion** of nuclear material and **misuse** of facilities

AL3.1: The IAEA can readily achieve technical objectives for safeguards

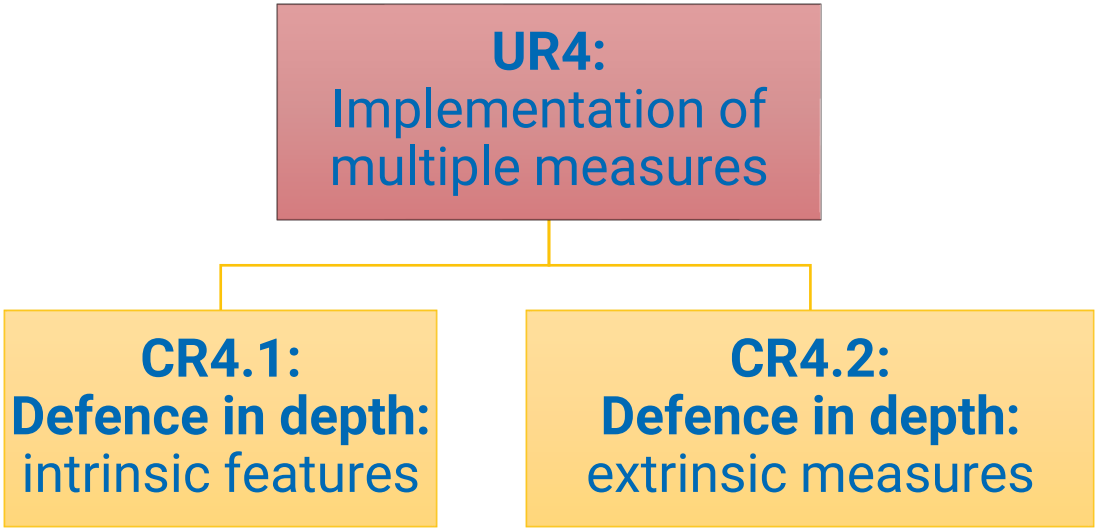
CR3.2: Efficient safeguards

IN3.2: Efficient execution of safeguards activities

AL3.2: The IAEA can thoroughly implement and **execute without undue delay** all foreseen safeguards activities

UR4: Implementation of Multiple Deterrence Measures

UR4: The NES should incorporate multiple proliferation resistance intrinsic features and extrinsic measures to deter diversion and misuse by the State



UR4: Indicators and Acceptance Limits

UR4: *implementation of multiple features and measures to* ***deter diversion and misuse by the State****.*

CR4.1: intrinsic features

IN4.1: NES has multiple intrinsic features for PR

AL4.1: NES incorporated redundant and diverse intrinsic features to reduce attractiveness of nuclear material and inhibit diversion or misuse

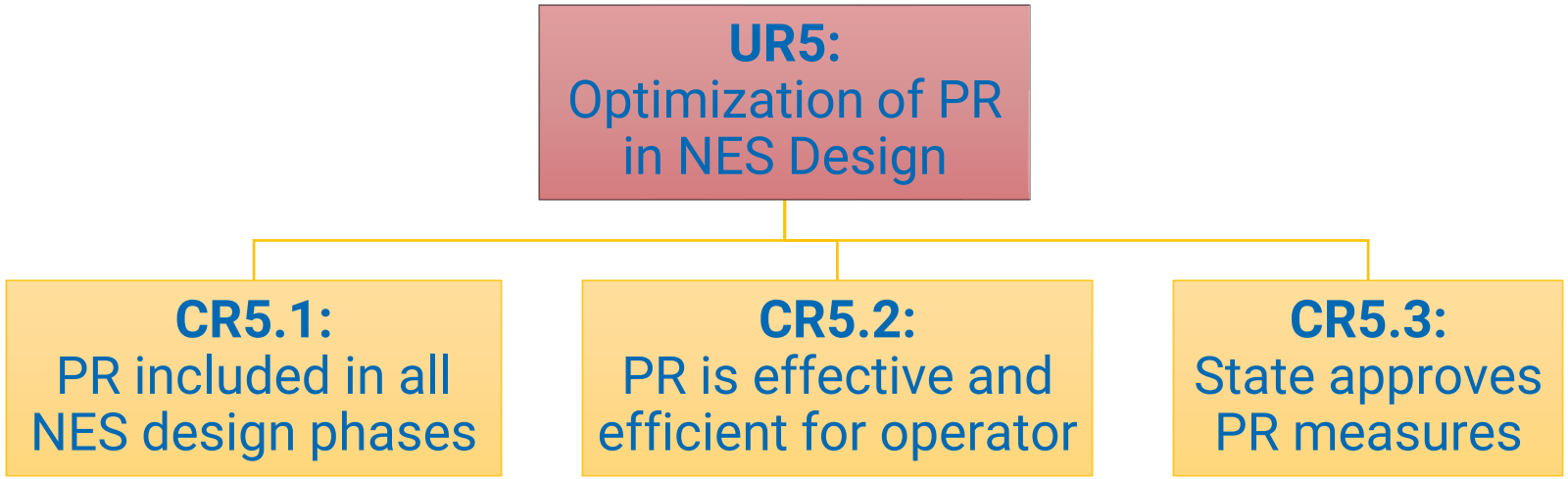
CR4.2: extrinsic measures

IN4.2: NES has multiple extrinsic measures for PR

AL4.2: NES incorporated complementary and redundant extrinsic measures to cover diversion of nuclear material and misuse by the State

UR5: Optimization of PR in NES Design

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 acceptable to operator and State.*



UR5: Indicators and Acceptance Limits

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* ***acceptable to the operator and approved by the State.***

CR5.1:
Inclusion of **PR in all NES design phases**

IN5.1: Incorporation PR in design and life cycle of NES
AL5.1: Designer/operator included PR in all design phases, and it covers the life cycle of the NES

CR5.2:
PR is **effective and efficient for operator**

IN5.2: Proliferation resistance of NES for operator
AL5.2: Implementation of PR intrinsic features and extrinsic measures is effective and efficient for the operator

CR5.3:
State approves PR measures

IN5.3: Proliferation resistance of NES for State
AL5.3: State approves the implementation of PR in the NES, and it meets requirements

Considerations

Proliferator needs

- Nuclear materials
- Technologies
- Skills & knowledge
- Time

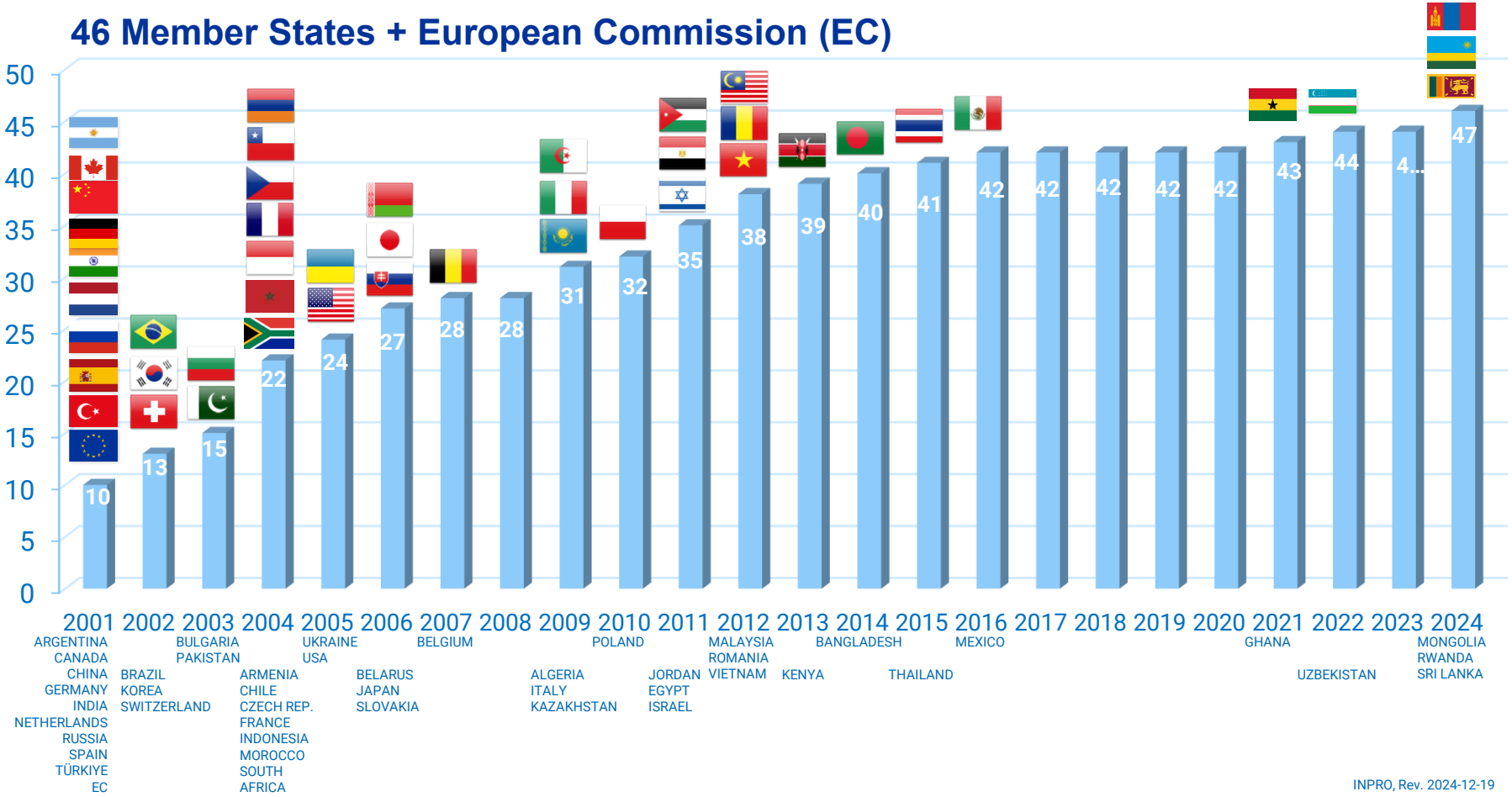
Fast reactors and associated fuel cycle facilities may contribute

- Variety of attractive nuclear materials and forms
- Capabilities: reprocessing, isotope separation, etc.
- Development of skills & knowledge

Intrinsic features: design
Extrinsic measures: State's commitments (i.e., AP), and IAEA safeguards

INPRO Members

46 Member States + European Commission (EC)



Thank you!

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