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International Atomic Energy Agency

How the IAEA helps ensure that nuclear energy is sustainable

Webinar organized by the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)

5 July 2022, 14:00 CEST

IAEA

INPRO
International Project on
Innovative Nuclear Reactors
and Fuel Cycles

Welcome

You can type your questions into the “Chat” panel

The webinar is being recorded and will be posted on the IAEA web-site for future viewing

Participants will be muted for the duration of the webinar

Maxim GLADYSHEV

Moderator

INPRO Task Leader for
“INPRO Dialogue & Outreach”

Speakers

Introducing INPRO
Brian BOYER, Head of INPRO Section

Achieving sustainable nuclear energy development
Mikhail KHOROSHEV, Former INPRO staff member and consultant to INPRO

Using the INPRO Methodology to assess sustainability of nuclear energy systems
Carolynn SCHERER, INPRO Task Leader

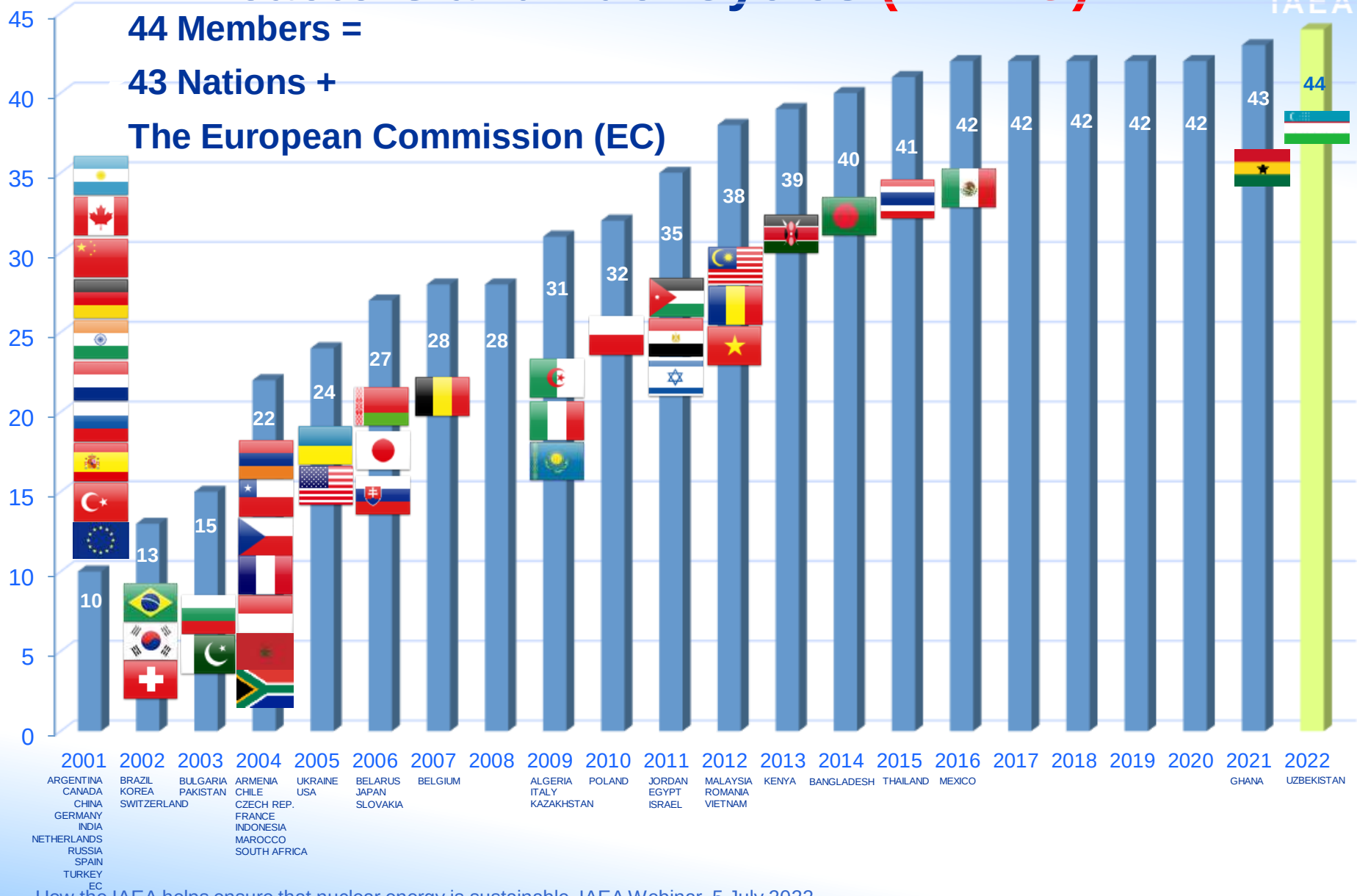
Nuclear energy development strategies and role of innovations
Alexander BYCHKOV, senior expert in INPRO

Introducing INPRO

Brian BOYER

- Section Head, INPRO
- 40 years of experience in nuclear energy analysis, safeguards, nuclear safety and educational outreach
  - Nuclear core design – USA Naval Reactors – Knolls Atomic Power Laboratory
  - Nuclear safety and safeguards R&D - USA Brookhaven and Los Alamos National Laboratories
  - IAEA Safeguards Inspector and Analyst
  - University engagement, mentoring and teaching in nuclear topics
  - Leading INPRO efforts
- Bachelors, Masters and Ph.D. (with Mech. Engineering Minor) in Nuclear Engineering from the Pennsylvania State University – Nuclear Safety and Experimental Condensing Flow Experiment Thesis Topics

International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)



Overall Objectives of INPRO

- Ensure nuclear energy is available to contribute, in a sustainable manner, to the growing energy needs of the current century and beyond
- Bring together all interested Member States in joint international and national innovation tasks in nuclear reactors and fuel cycles promoting sustainability in Infrastructure, Economics, Safety, Environment, Waste Management and Proliferation Resistance

UN Sustainability Goals and INPRO

INPRO and IAEA Nuclear Energy Sustainability Focus Goals

INPRO Task Structure

Task 1: Global Scenarios

TOOLS / SERVICES

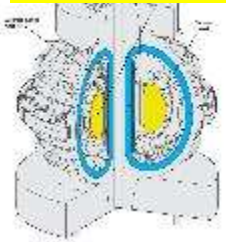
ASENES

Scenario modelling and analysis	Economic analysis and evaluation of Nuclear Energy System (NES)	Comparative evaluation of NESs and scenario options	Road mapping towards enhanced NE sustainability
MESSAGE-NES	NEST	KIND-ET	ROADMAPS-ET

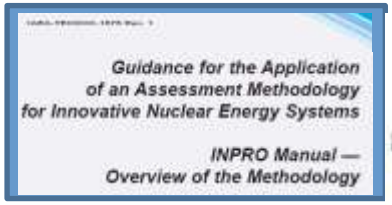
Task 2: Innovations

Transportable NPP Akademik Lomonosov

Fusion Studies

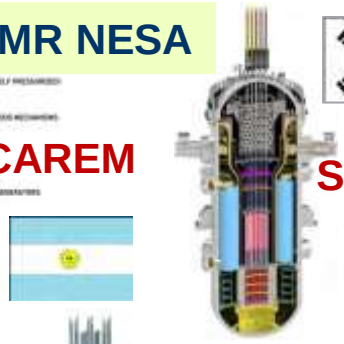


Task 3: Sustainability Assessment and Strategies



SMR NESA

CAREM



SMART

Task 4: Dialogue & Outreach

2021
18th and 19th Dialogue Forum

2022
20th Dialogue Forum
USA NOV 2022

RITM-200M

Conclusion

- INPRO is a key forward looking IAEA activity assessing nuclear energy systems integrated with the “One House” of the IAEA
- The INPRO members are key drivers of projects and tasks in INPRO
- Assessing and evaluating nuclear energy systems in the 6 key areas provides key sustainability keys for moving nuclear power plans ahead in the 21st century
- INPRO strives in all tasks for studying, promoting, and creating sustainability in nuclear energy systems and national and international nuclear fuel cycles tied into existing and planned activities

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Thank you for your attention

Introducing INPRO

Brian BOYER
Head of INPRO Section

Achieving sustainable nuclear energy development

Mikhail KHOROSHEV

- Ph.D. Nuclear engineering
- 30+ years of experience in nuclear energy
  - Worked in the IAEA Nuclear Energy Department as scientific secretary for many projects
  - Organised over 70 IAEA meetings and published many technical reports
  - Has over 50 publications including scientific journals, IAEA TECDOCs and Nuclear Energy Series reports, proceedings of international conferences, web-based knowledge portals and databases
  - Development of INPRO methodology, IAEA tools and comparative assessment strategies for assessing Nuclear Energy during the first 7 years since the establishment of the project
- In his early career worked as a research fellow, senior scientist, nuclear engineer, consultant and project manager at Russian Research Centre “Kurchatov Institute”, German Reseach Centre KFA-Juelich, Netherlands Energy Research Foundation ECN-Petten, French-German organisation for safety of nuclear installations, United Nations Industrial Development Organisation (UNIDO)

UN Concept of Sustainability

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs

GOAL: To achieve equity within and across countries as well as across generations, by integrating growth, environmental protection and social welfare

1987 UN Report "Our Common Future" written by international group of politicians, civil servants and experts on the environment and development (Brundtland report, in recognition of the chair of the World Commission on Environment and Development)

UN Concept of Sustainability and INPRO

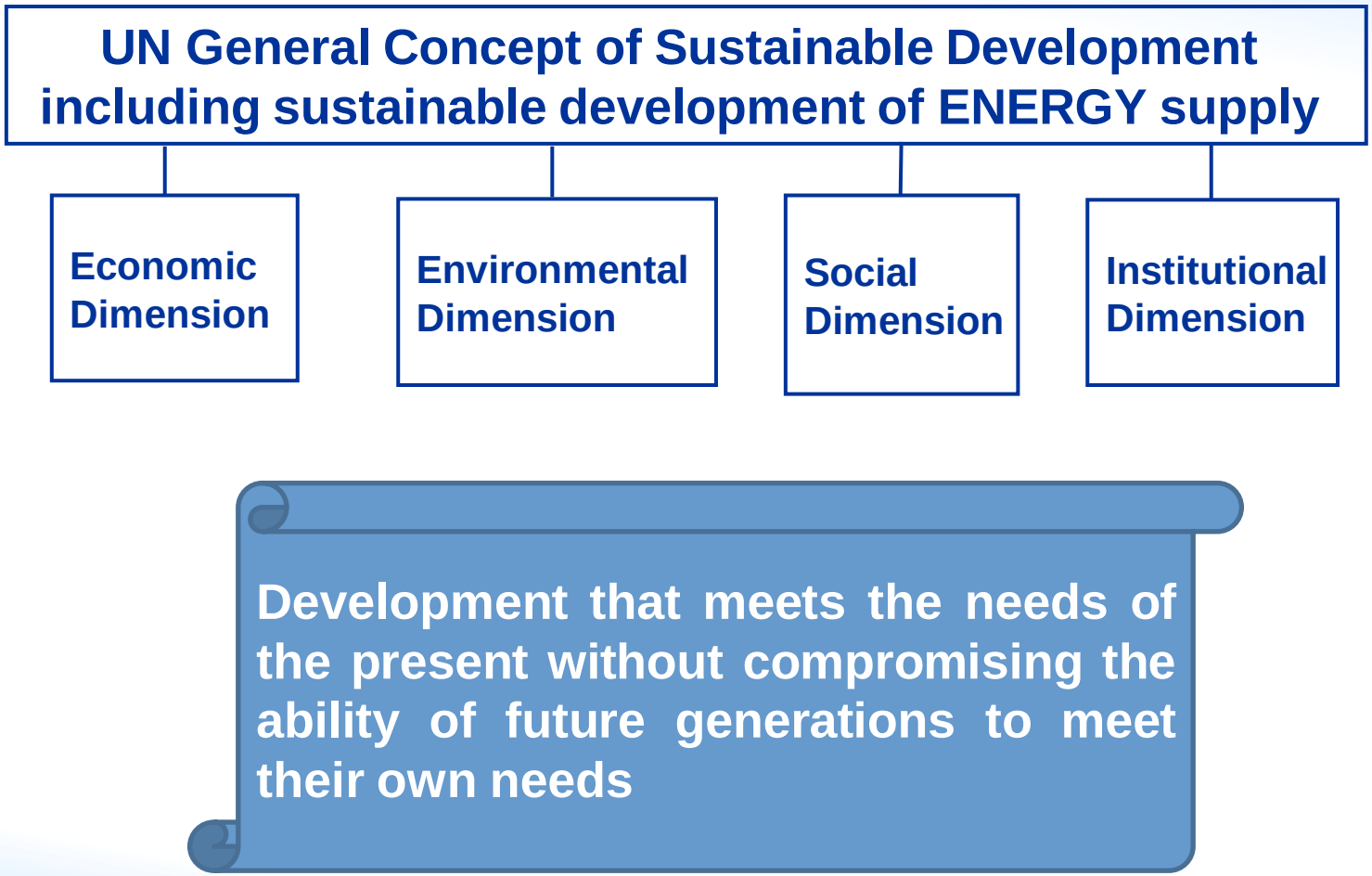
UN General Concept of Sustainable Development including sustainable development of ENERGY supply

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs

Role of energy supply in sustainability concept

- **Energy supply is fundamental to sustainable development of the world**
- **Sustainable energy supply needs significant contribution by NE**

UN Concept of Sustainability and INPRO



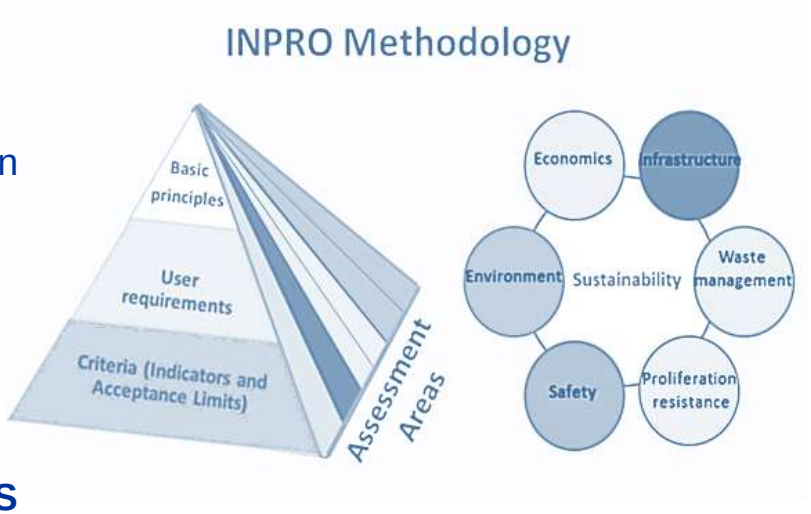
INPRO Objectives

The overall objective of INPRO is to help ensure that nuclear energy is available to contribute, in a sustainable manner, to the growing energy needs of the current century and beyond

To bring together technology holders and users to jointly consider national and international actions required for achieving desired innovations in nuclear reactors and fuel cycles

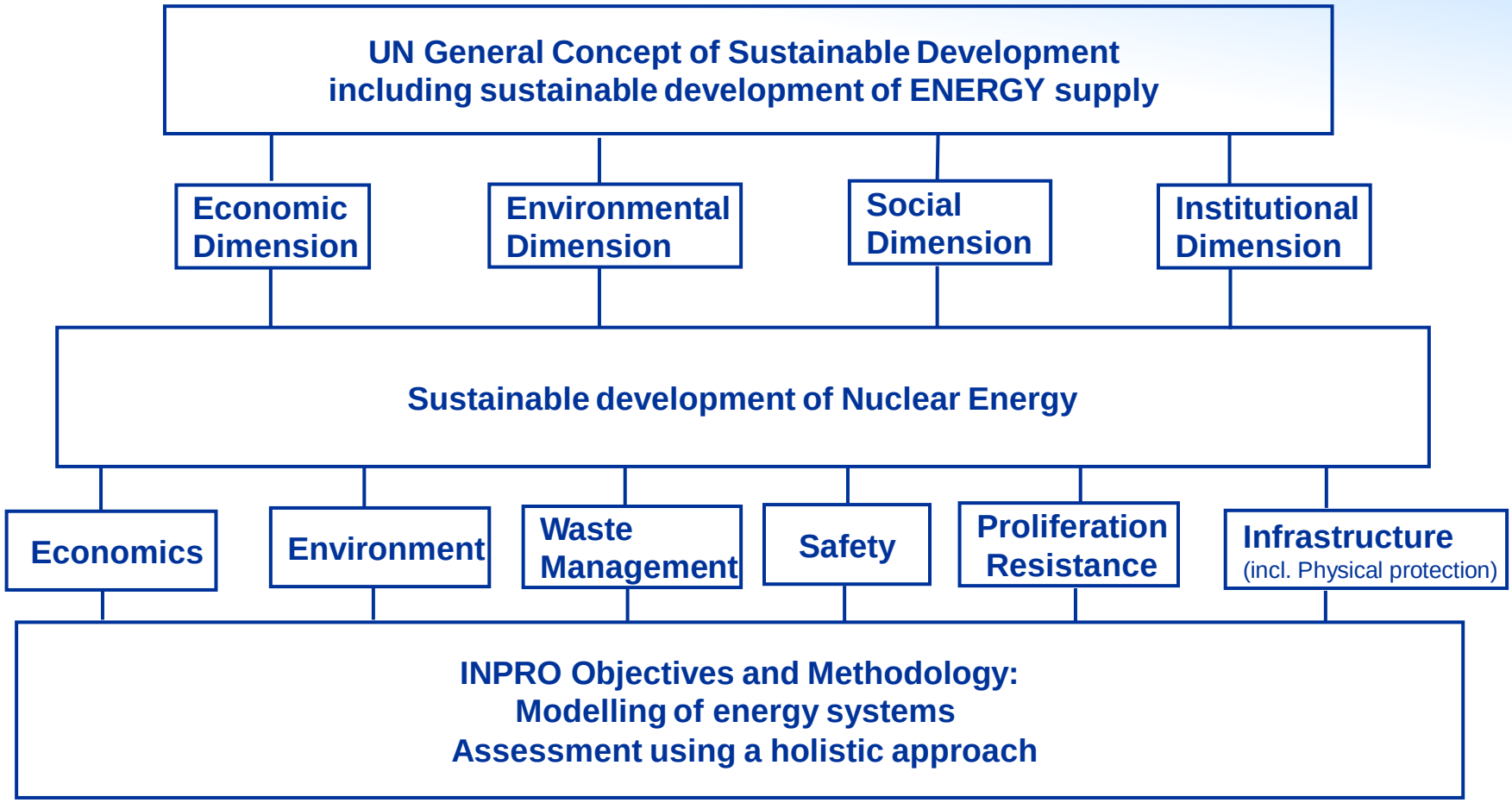
INPRO's holistic apprach

- **Innovative Nuclear Energy System (NES):**
- **Innovative NES position NP to make major contribution to energy of the current century and beyond**
- **Evolutionary and Innovative and Designs in NES.**
  - Evolutionary design (= advanced design) incorporating small to moderate modifications with strong emphasis on maintaining design proofness.
  - Innovative design (= advanced design) incorporating radical conceptual changes in design approaches or system configuration in comparison with existing designs.
- **NES includes all Components:**
  - Mining and Milling
  - Conversion
  - Enrichment
  - Fuel Fabrication
  - Reactors - Energy Production
    - Electrical, Heating, H_2 Production, Desalination
    - Integration with Fossil, Solar, Wind
  - Reprocessing
  - Materials Management (incl. Transportation and Waste Management)
- **Institutional Measures (e.g., safeguards, etc.)**
- **NES includes all Phases (e.g., cradle to grave)**



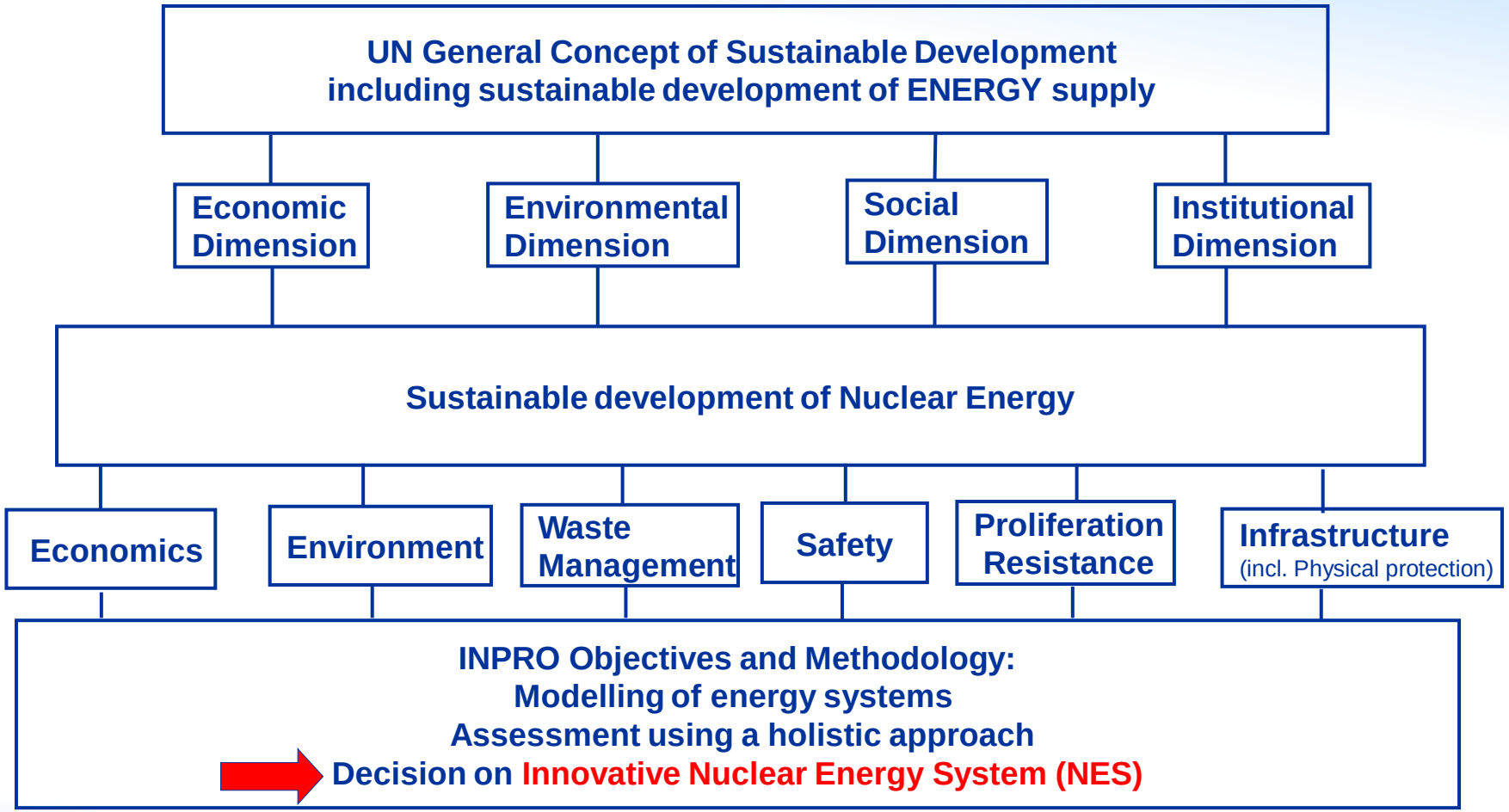
INPRO Methodology is a tool for comprehensive NES sustainability assessment and identifying gaps in sustainability of a particular NES

UN Concept of Sustainability and INPRO



- Energy supply is fundamental to sustainable development of the world
- Sustainable energy supply needs significant contribution by NE
- INPRO assures that NE is available in a sustainable manner in the 21st century and beyond
- **INPRO addresses all dimensions of the concept of Sustainability**

UN Concept of Sustainability and INPRO



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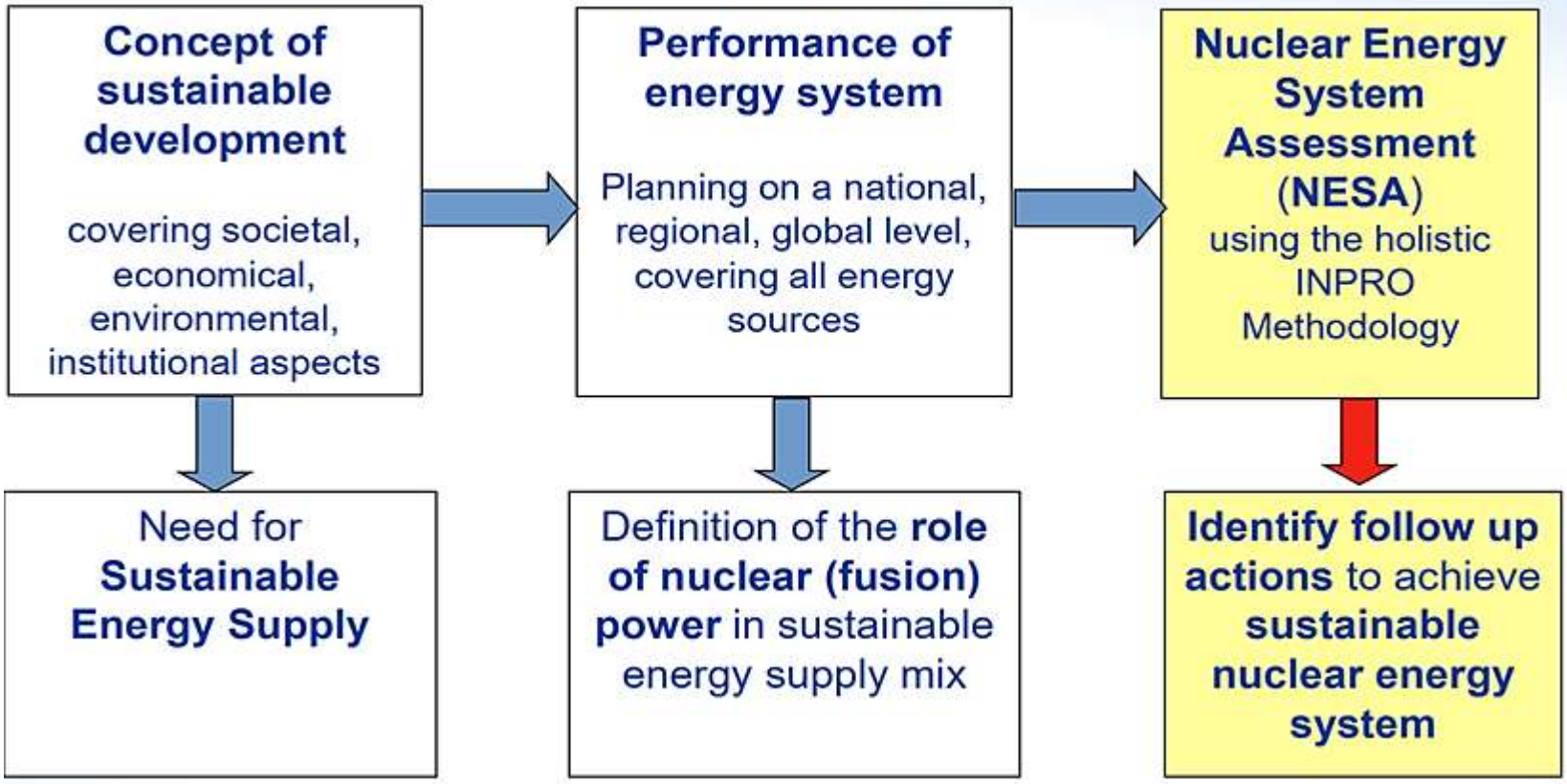
- INPRO addresses all dimensions of the concept of Sustainability

Sustainable Development – Developing a Nuclear Energy System



Take aways
INPRO and UN sustainability concept

The UN's general concept of sustainable development

- incorporated in the INPRO objectives
- integrated into the INPRO methodology
- INPRO addresses all dimensions of the UN concept of Sustainability

Sustainability of nuclear energy system – the ability of a NES to operate sustainably for least one hundred years and beyond

The INPRO Methodology for the assessment of NES sustainability

- identified six topical areas of relevance to NES sustainability assessment: *economics, environmental impact, safety, proliferation resistance, waste management and infrastructure*

NES is sustainable if it fulfils

all INPRO criteria in all INPRO methodology areas

Take aways
INPRO and UN sustainability concept

INPRO Method:

- Modelling of energy systems
- Assessment using a holistic approach
- Decision on Innovative Nuclear Energy System (NES)

INPRO contributes to furthering the global development of sustainable energy by:

1) creating a standardized methodology for assessing the potential of NES
2) bringing together both technology holders and technology users to consider jointly the international and national actions required to achieve desired innovations
3) creating a forum to involve all relevant stakeholders and fostering ongoing initiatives at the national and international level.

INPRO assures that NE is available in a sustainable manner of the current century and beyond

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Thank you for your attention

Achieving sustainable nuclear energy development

Mikhail KHOROSHEV
Expert in INPRO

Using the INPRO Methodology to assess sustainability of nuclear energy systems

Carolynn SCHERER

- Nuclear Engineer, INPRO Section
  Task 3 Leader: Sustainability Assessment and Strategies
- Over 30 years' experience in nuclear energy
  - Nuclear fuel fabrication
  - Nuclear non-proliferation, security and safeguards
  - International cooperation in nuclear material accounting and control
- Master's degree in Ceramic Science from The Pennsylvania State University, Certified Project Management Professional (PMP), 30+ years at Los Alamos National Laboratory, flute player

Content

I. Brief history INPRO methodology

II. Overview of the INPRO methodology

III. Nuclear Energy System Assessments (NESA)

IV. Benefits of NESA

V. Why is a NESA important

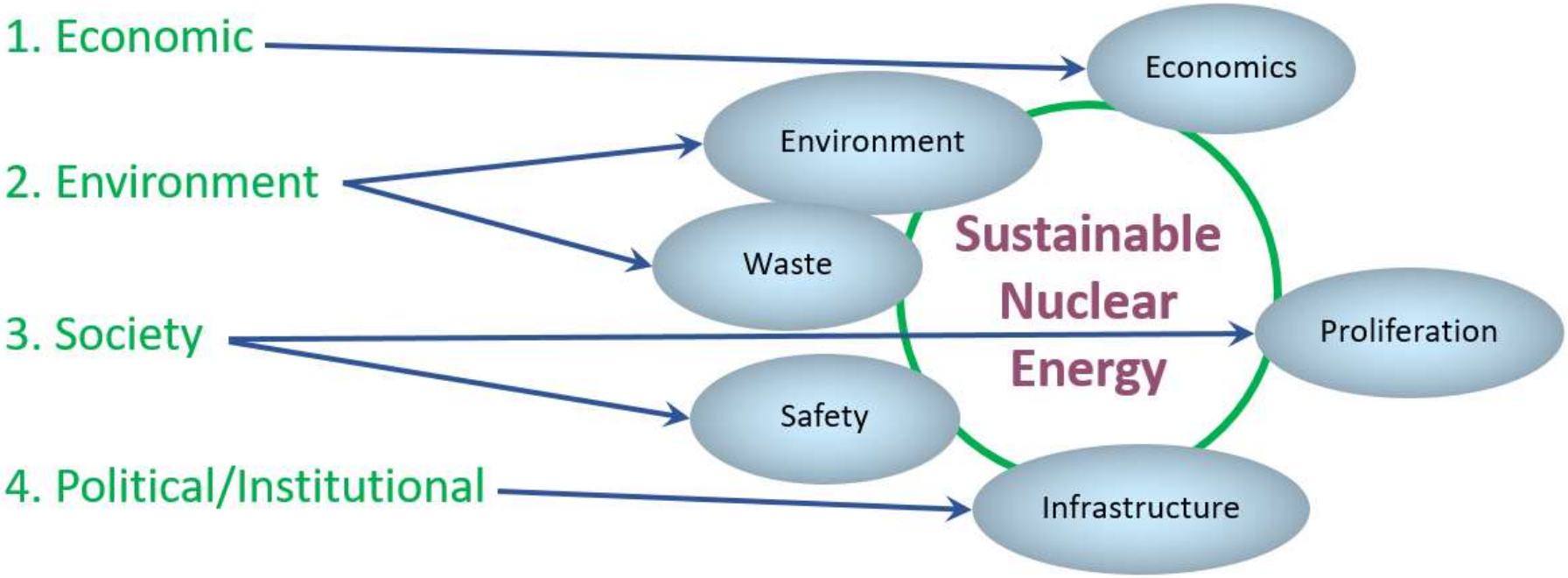
Brief History

- IAEA tool for assessing sustainability through a **Nuclear Energy System Assessment (NESA)**
- First published in 2003, updated in 2008, major revisions 2014-2022
- Contribution from 300+ national and international experts
- Several assessments performed and published as IAEA TECDOCs
  - Limited Scope Sustainability Assessment of Planned Nuclear Energy Systems Based on BN-1200 Fast Reactors, IAEA-TECDOC-1959 (2021)

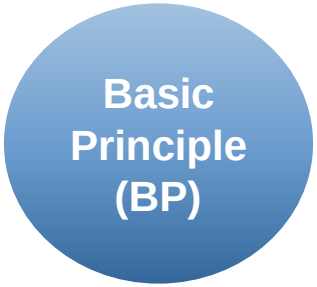
INPRO Methodology Developed to Address Nuclear Energy Sustainability

UN concept for sustainable development of energy

INPRO methodology for sustainability assessment

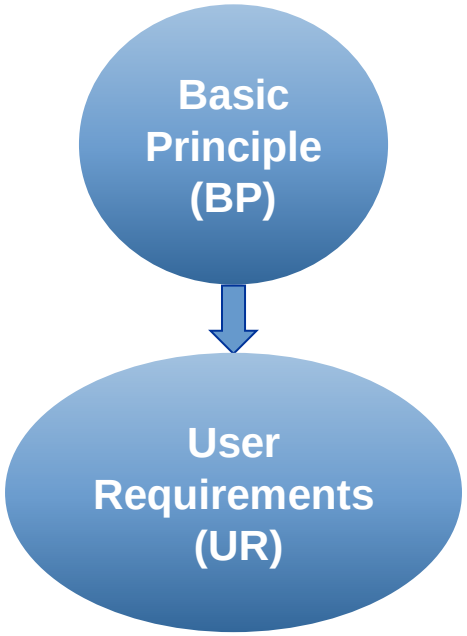


INPRO Methodology: Foundation



Goals for the development of a sustainable Nuclear Energy System (NES)

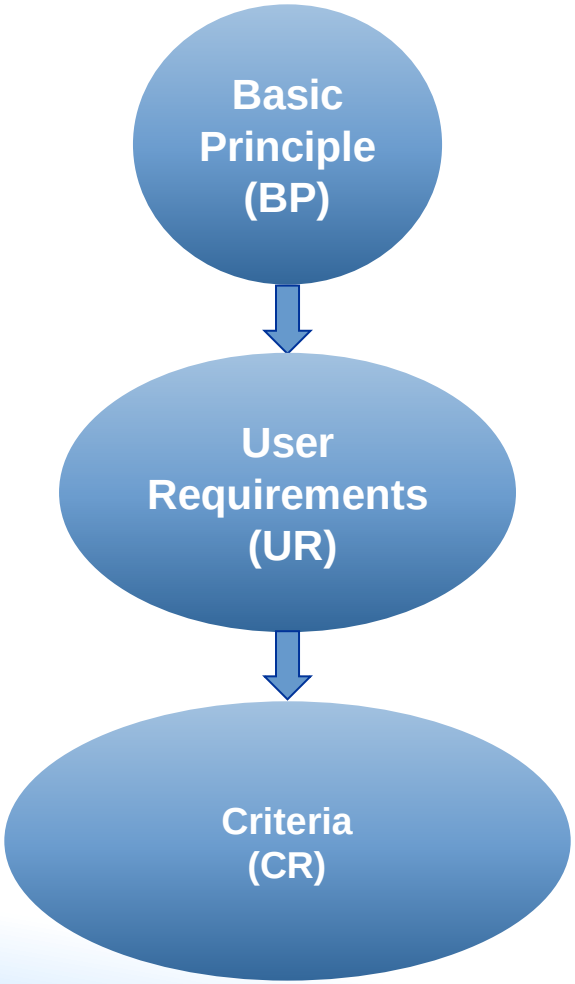
INPRO Methodology: Foundation



Goals for the development of a sustainable Nuclear Energy System (NES)

Requirements to meet goal defined in Basic Principle (BP) for designers, operators, industry and/or State

INPRO Methodology: Foundation

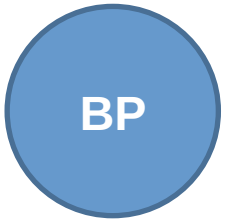


Goals for the development of a sustainable Nuclear Energy System (NES)

Requirements for designers, operators, industry and/or State to meet goal defined in Basic Principle (BP)

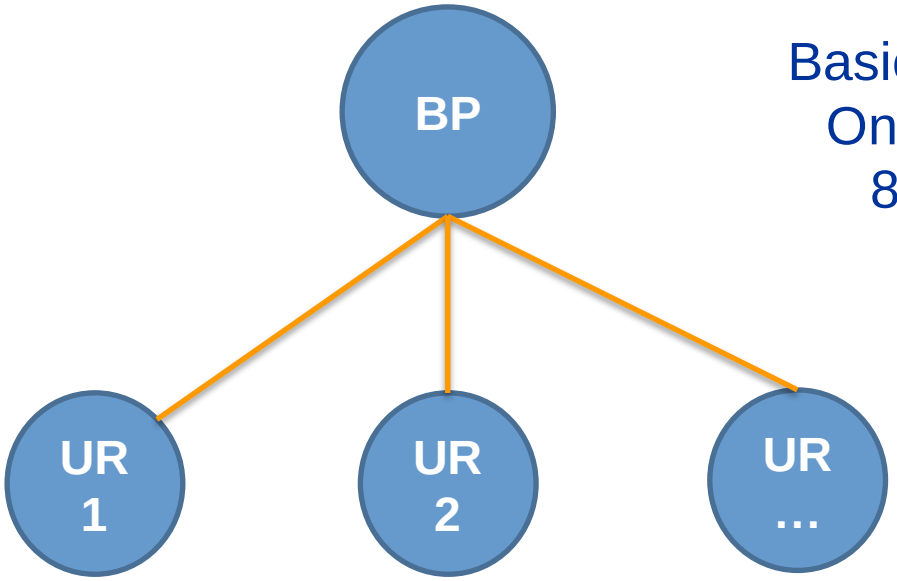
Assessor's tool to check metrics for NES to support meeting User Requirements (URs)

INPRO Methodology Structure



Basic Principle (BP):
One per INPRO area –
8 BPs total

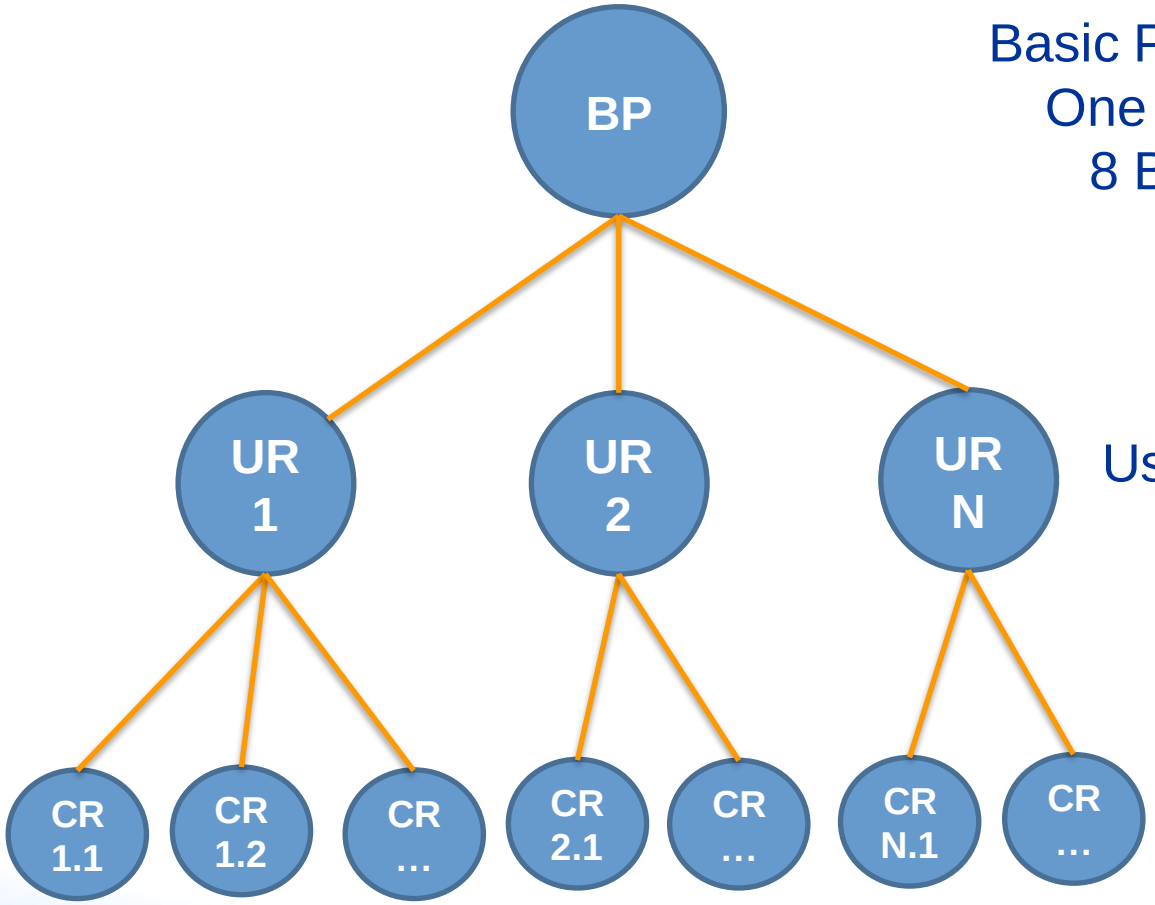
INPRO Methodology Structure



Basic Principle (BP):
One per INPRO area –
8 BPs total

User Requirements (UR):
2-7 UR per BP

INPRO Methodology Structure



Basic Principle (BP):
One per INPRO area –
8 BPs total

User Requirements (UR):
2-7 UR per BP

Criteria (CR):
1-6 CR per UR

INPRO Methodology Structure

CR supported with:

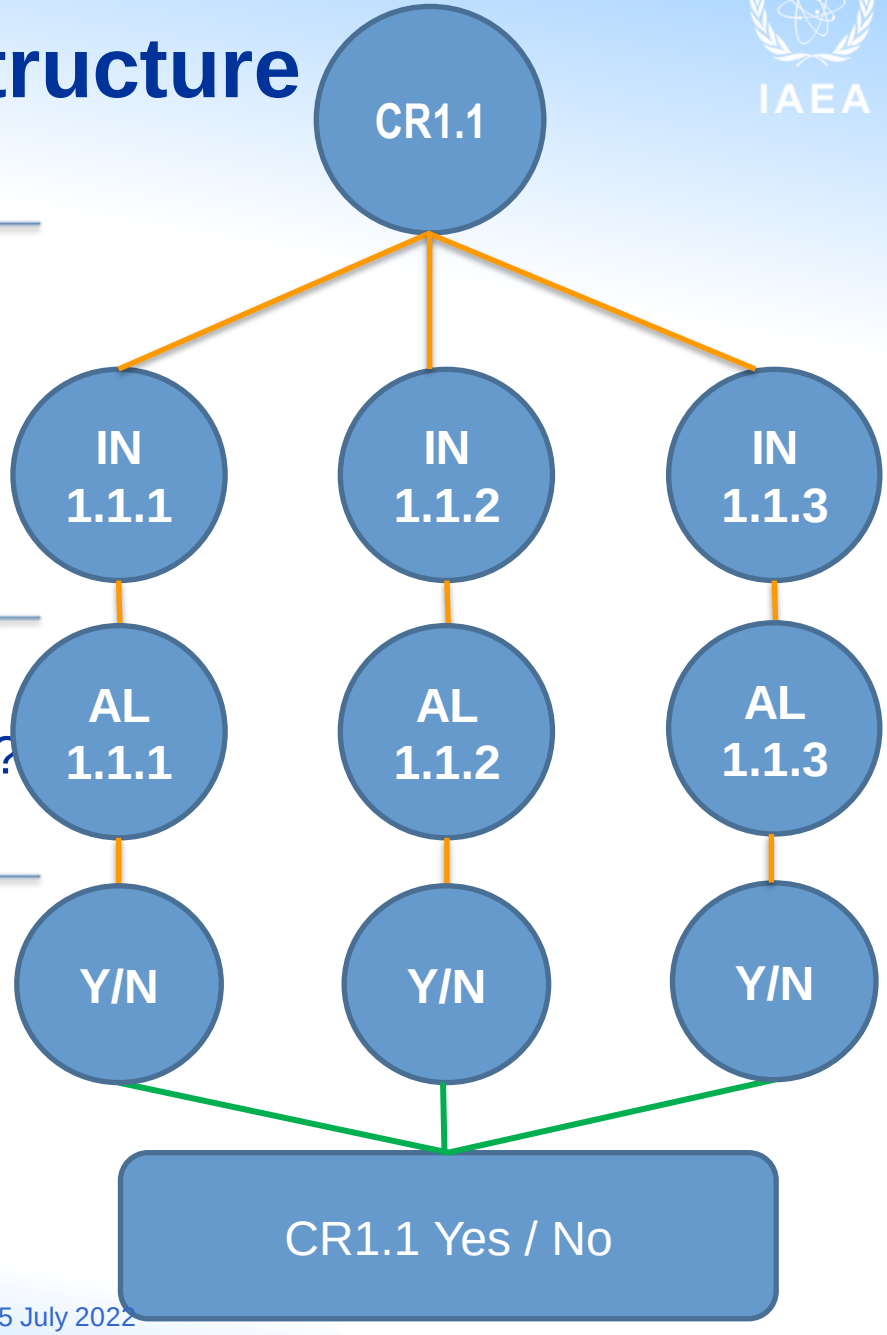
- Indicators (IN)
- Acceptance limits (AL)

Assessor:

- does design meet Acceptance Limit?
- Yes or No

If all indicators (IN) met

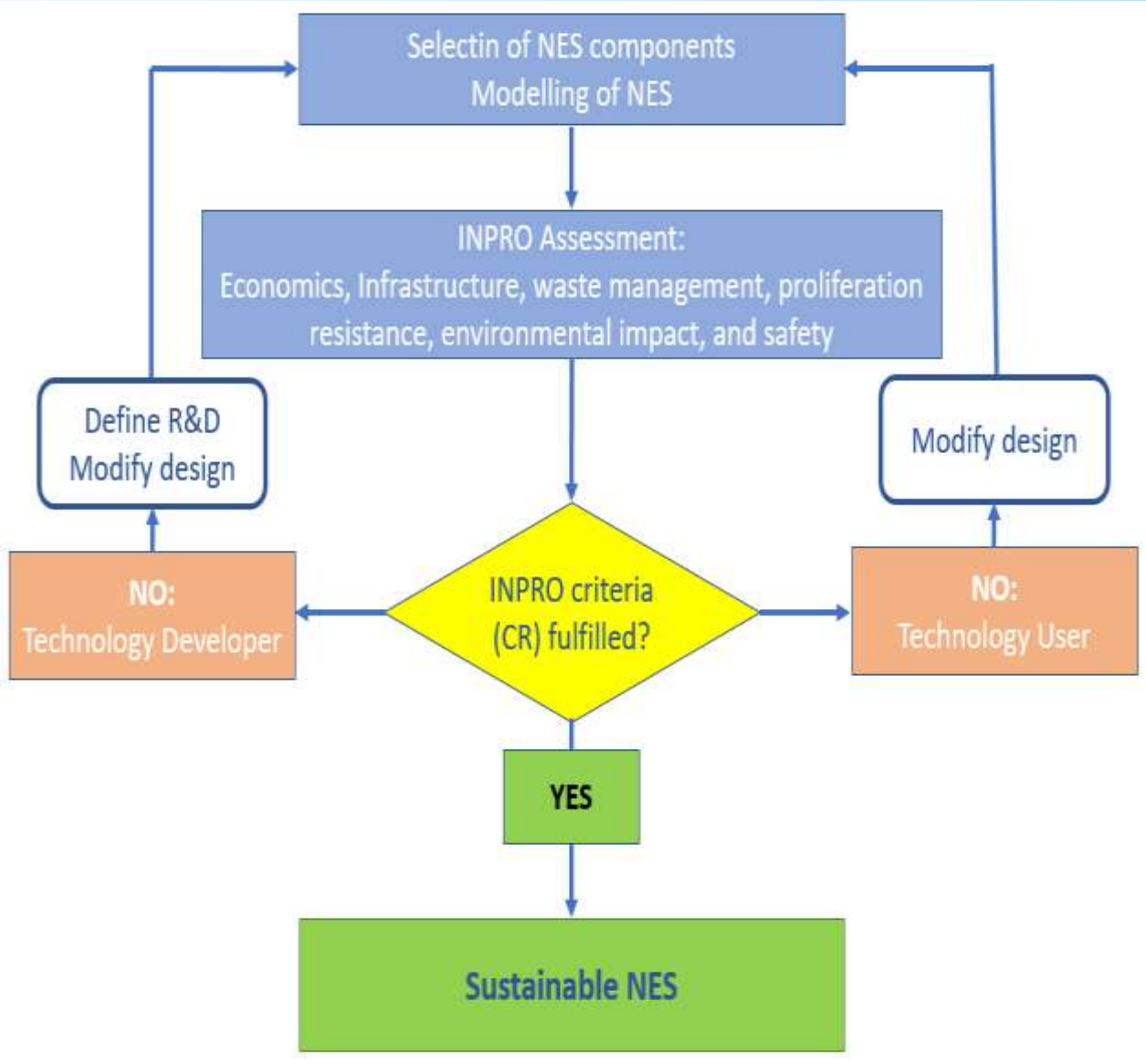
- CR met



How do we do an Assessment? (NESA)

Criteria Fulfilled:

- Yes - sustainable
- No
  - Areas to modify NES (identifies **gaps** and **improvement areas**)
  - Modify NES / design
  - Perform R&D
  - Reassess
- Confirmation of NES Sustainability



NESA: Evolutionary & Innovative Designs

Progressive

- Toward improved metric
- Development reduces uncertainty
- Identify R&D needs

NESA: Evolutionary & Innovative Designs

Progressive	• Toward improved metric • Development reduces uncertainty • Identify R&D needs
Comparative	• Performance on a metric for 2 options • Select better option or set of options • Examine synergies between options

NESA: Evolutionary & Innovative Designs

Progressive	• Toward improved metric • Development reduces uncertainty • Identify R&D needs
Comparative	• Performance on a metric for 2 options • Select better option or set of options • Examine synergies between options
Innovative	• Forward-looking target value for a metric • Less impact on environment, better economics, better use of resources, etc. • Identify R&D needs

NESA is for Newcomer Country

Newcomer Country

- Limiting scope
- Using a graded approach
- Increasing awareness of long-term issues
- Assisting with planning and decision making

NESA is for State / Government Institutions

Newcomer Country	State / Government Institutions
• Limiting scope • Using a graded approach • Increasing awareness of long-term issues • Assisting with planning and decision making	• Maintaining or expanding NES • Comparing options • Identifying gaps (areas of improvement) • Identifying potential synergies amongst NES combinations

NESA is for National Industry

Newcomer Country	State / Government Institutions	National Industry
• Limiting scope • Using a graded approach • Increasing awareness of long-term issues • Assisting with planning and decision making	• Maintaining or expanding NES • Comparing options • Identifying gaps (areas of improvement) • Identifying potential synergies amongst NES combinations	• Comparing options • Identifying improvements • Identifying areas for research and development

NESA is for Technology Developers

Newcomer Country	State / Government Institutions	National Industry	Designer / Technology Developer
• Limiting scope • Using a graded approach • Increasing awareness of long-term issues • Assisting with planning and decision making	• Maintaining or expanding NES • Comparing options • Identifying gaps (areas of improvement) • Identifying potential synergies amongst NES combinations	• Comparing options • Identifying improvements • Identifying areas for research and development	• Guiding development • Comparing options • Identifying options with advantages • Identify areas for R&D

Support for Performing NESA

INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Economics
IAEA Nuclear Energy Series No. NG-T-4.4
(90 pp.; 2014) • ISBN 978-92-0-102714-6 • STI/PUB/1653 • €40.00

INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Proliferation Resistance
IAEA-TECDOC-1575, Vol. 5
2008 – under revision

INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Infrastructure
IAEA Nuclear Energy Series No. NG-T-3.12
(68 pp.; 2014) • ISBN 978-92-0-106214-7 • STI/PUB/1668 • €33.00

INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Waste Management
IAEA-TECDOC-1901
(74 pp., 10 figs; 2020) • ISBN 978-92-0-102520-3 • IAEA-TECDOC-1901 • €18.00

INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Environmental Impact from Depletion of Resources
IAEA Nuclear Energy Series No. NG-T-3.13
(62 pp., 25 figs; 2015) • ISBN 978-92-0-103415-1 • STI/PUB/1700 • €33.

INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Safety of Nuclear Reactors
IAEA-TECDOC-1902
(110 pp., 5 figs; 2020) • ISBN 978-92-0-102720-7 • IAEA-TECDOC-1902 • €18.00

INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Environmental Impact of Stressors
IAEA Nuclear Energy Series No. NG-T-3.15
(94 pp., 5 figs; 2016) • ISBN 978-92-0-101616-4 • STI/PUB/1733 • €38.00

INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Safety of Nuclear Fuel Cycle Facilities
IAEA-TECDOC-1903
(168 pp., 8 figs; 2020) • ISBN 978-92-0-102920-1 • IAEA-TECDOC-1903 • €18.00

New IAEA e-learning course
Analysis Support for Enhanced Nuclear Energy Sustainability
https://elearning.iaea.org

Why are Nuclear Energy System Assessments (NESA) important?

- Assess nuclear energy systems (NES) for sustainability
  - NES lifecycle, over a century (multigenerational)
  - All nuclear fuel cycles

- Sustainable:
  - Meet needs of the present, without compromising future generations to meet their needs
  - Address limitations imposed by technology and social organization on the environment's ability to meet present and future needs

- Areas of assessment
  1. Infrastructure – legal and regulations, not overly burdensome
  2. Economics – affordable over lifetime
  3. Safety – as safe or safer than current generation
  4. Proliferation resistant –not contribute to material for nuclear weapons
  5. Environmental – resources available, less impact on planet & humans
  6. Waste management – addresses long-term solutions, permanent/safe

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Thank you for your attention

Using the INPRO Methodology to assess sustainability of nuclear energy systems

Carolynn SCHERER
INPRO Task Leader

Nuclear energy development strategies and role of innovations

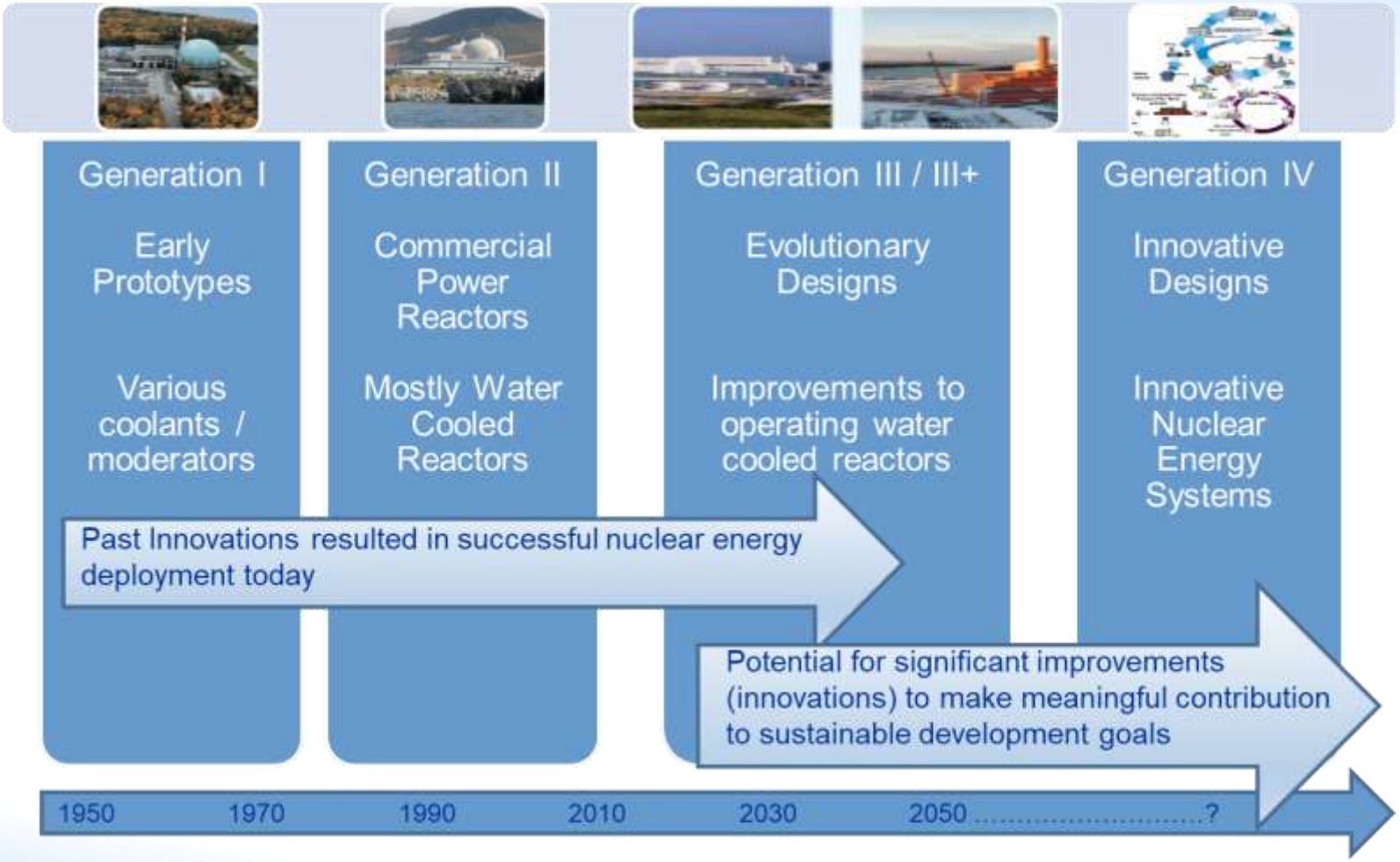
Alexander BYCHKOV

- Senior nuclear engineering expert, INPRO Section
- Before re-joining IAEA had diplomatic post of ROSATOM's representative to the International Organizations in Vienna
- IAEA Deputy Director General, Head of the Department of Nuclear Energy, from 2011 till 2015
- From 2006 till 2011 served as Director General of the Research Institute of Atomic Reactors in Dimitrovgrad, Russian Federation, were worked from 1982.
- Graduated in chemistry from Moscow State University in 1982
- Main areas of R&D activity cover: the nuclear fuel cycle subjects including nuclear fuel, pyro-processing, fast reactors and high level wastes, radionuclide technologies and research reactors applications. He is expert in international cooperation and political aspects of nuclear energy.
- Dr Bychkov is a co-author of more than 150 scientific publications

Introduction

- INPRO is forward-looking activity
- INPRO promotes the innovation in the areas of:
  - Nuclear reactors
  - Nuclear fuel cycles: front-end and back-end
  - Institutional approaches for nuclear power
- INPRO assists the Member States in National strategic and long-term planning
- INPRO develops and provides tools and services
- INPRO promotes the Partnerships for Nuclear Futures

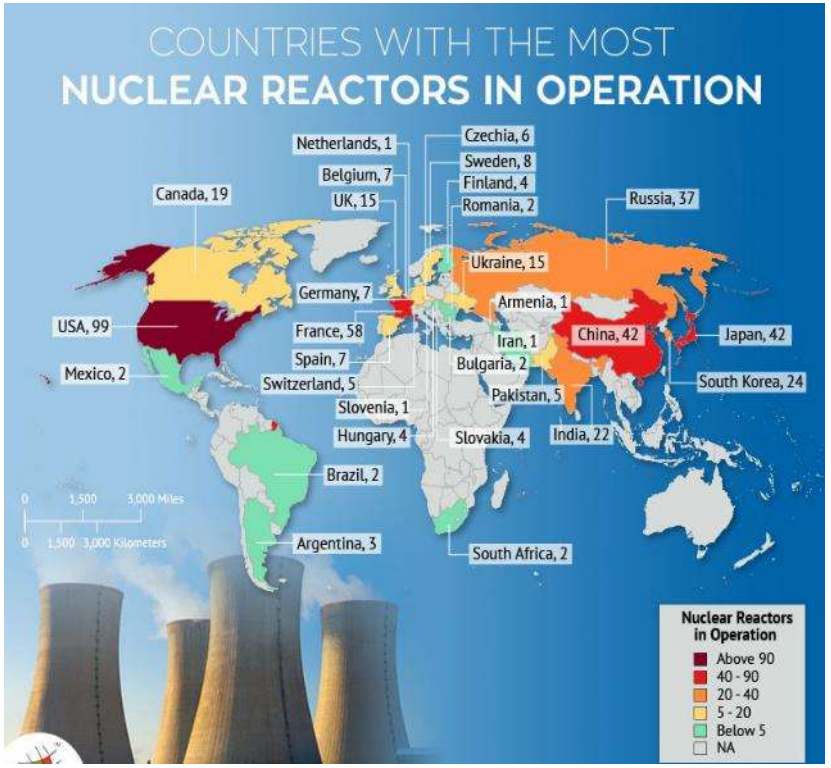
Nuclear Power Deployment Evolution



INPRO Task: Global Scenarios

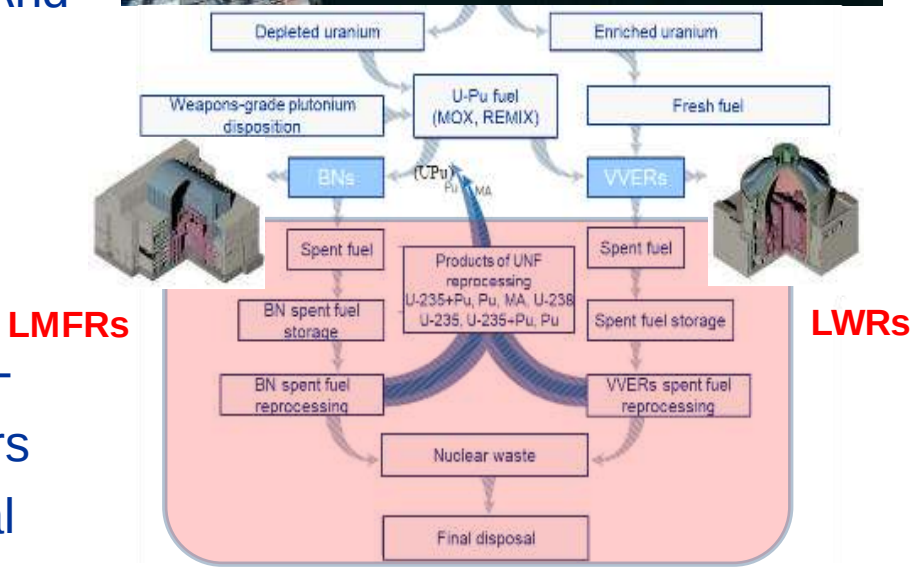
➢ Main directions

- Develop global and regional nuclear energy scenarios
- Use developed scientific-technical analysis tools
- Provide a global vision of sustainable nuclear energy development in the current century and beyond
- Forge innovative new partnerships
- Analysis Support for Enhanced Nuclear Energy Sustainability - ASENES – Key New Service



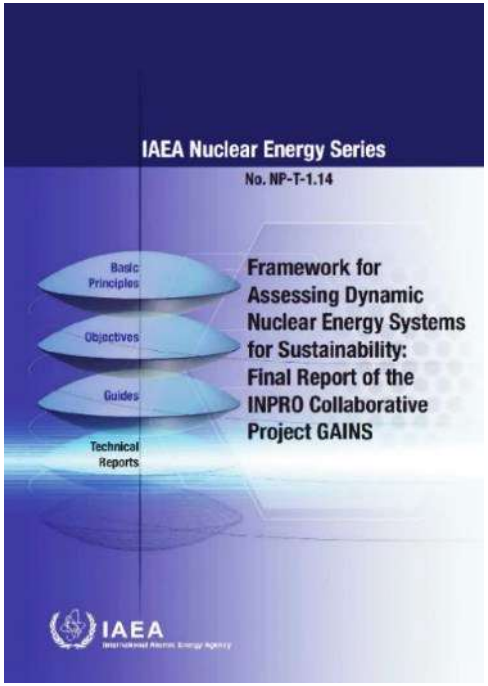
INPRO Task: Innovations

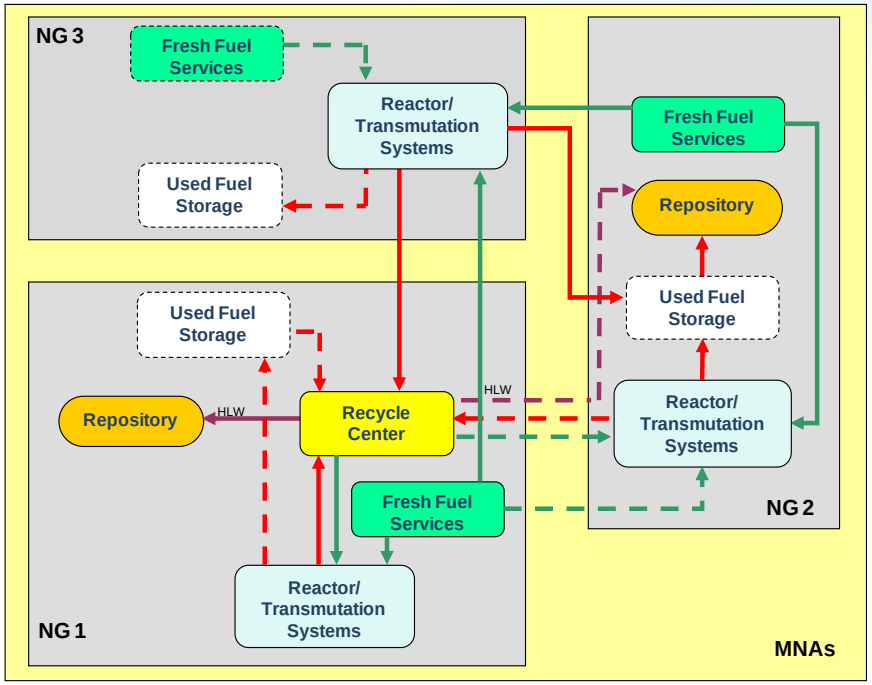
- **Current studies on innovations in nuclear energy technology and institutions:**
  - Case studies for the Deployment of Factory Fuelled SMRs
  - Review of Innovative Reactor Concepts For Prevention of Severe Accidents And Mitigation of Their Consequences (RISC)
  - WIRAF – Waste arisings from innovative reactors and fuel cycles
  - Cooperative Approaches to the Back-end of the Nuclear Fuel Cycle: Drivers and Institutional, Economic and Legal Impediments



International Architecture of Innovative Nuclear Power and Nuclear Fuel Cycle

2013

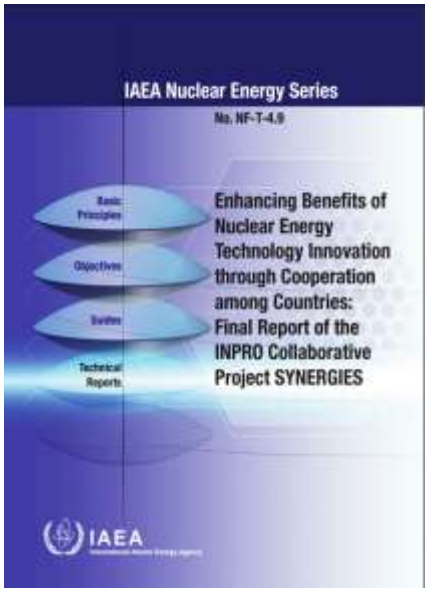




- GAINS project - transition scenarios to future nuclear energy systems
- The most important element is a heterogeneous world model with different policies regarding NFC front-end and back-end

INPRO Strategic Studies on Enhanced Nuclear Energy System

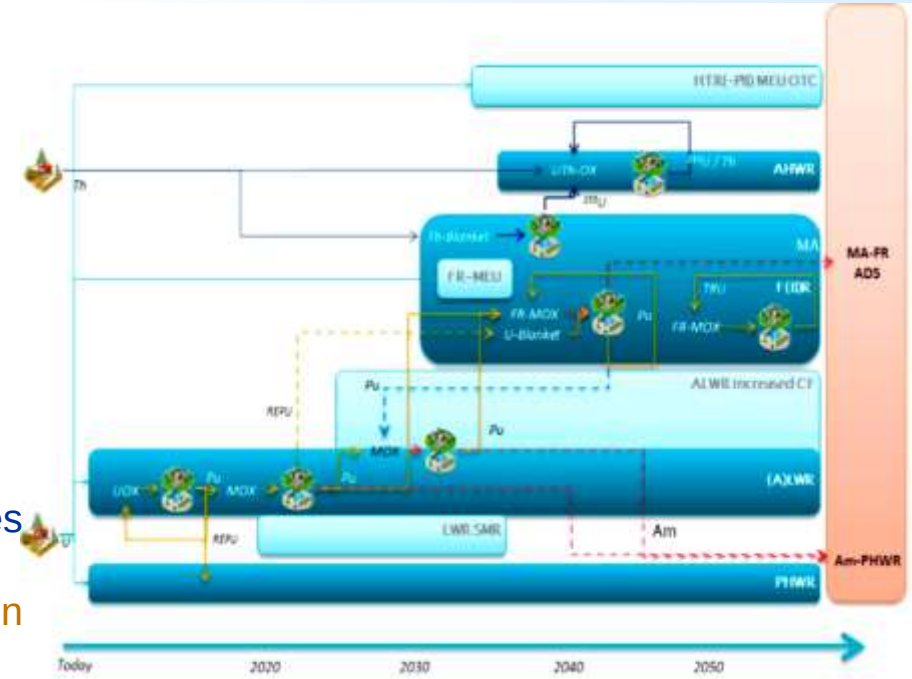
2018



The INPRO collaborative project "Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability" (SYNERGIES) has systematized options to enhance nuclear energy sustainability.

Enhanced sustainability may be achieved through:

- Innovations in technologies and/or changes in policies,
- Enhanced collaboration among countries



Technology related options may be structured along NFC types:

- Once-through
- Limited recycling of SNF
- MA or MA+FP transmutation
- Recycle with only physical processing
- Complete recycle of SNF
- Final geological disposal of all wastes

With advances in reactor technology sustainability can be enhanced within each NFC option

“Analysis Support for Enhanced Nuclear Energy Sustainability: an INPRO Service to Member States” (ASENES)

Collaborative Projects → Methods, Tools And Project Publications → Service to MSs: ASENES

GAINS - Global Architecture of Innovative Nuclear Energy Systems with Thermal and Fast Reactors and a Closed Fuel Cycle

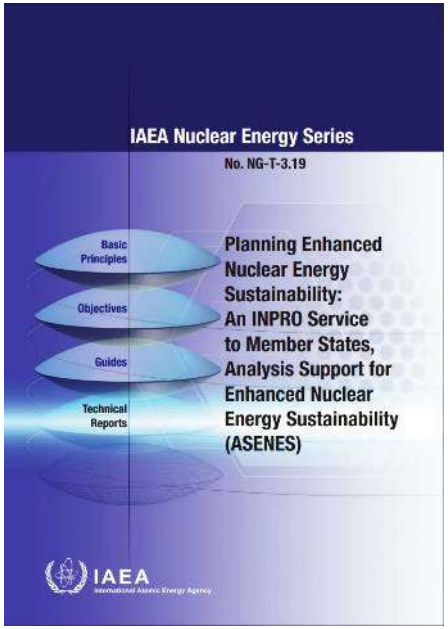
SYNERGIES - Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability

KIND/CENESO - Key Indicators for Innovative Nuclear Energy Systems

ROADMAPS - Roadmaps for a Transition to Globally Sustainable Nuclear Energy Systems

Project outputs include methods and software tools that could be further used by MSs for similar or alternative studies

ASENES - Analysis Support for Enhanced Nuclear Energy Sustainability



2021

ASENES Service: toolkit

ASENES

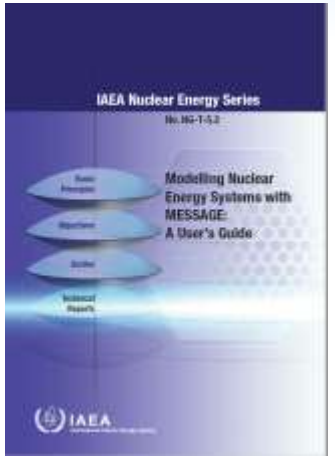
MESSAGE NES
Framework for nuclear energy scenario modelling

NEST
Nuclear energy economic analysis

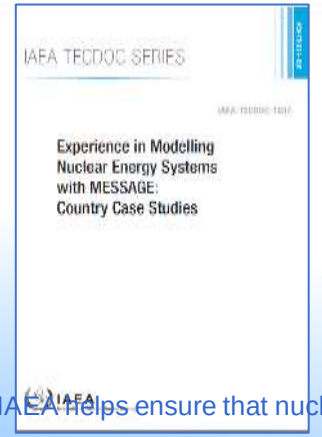
KIND-ET
Comparative evaluation of NES/scenario options

ROADMAPS-ET
Road mapping for enhanced nuclear energy sustainability

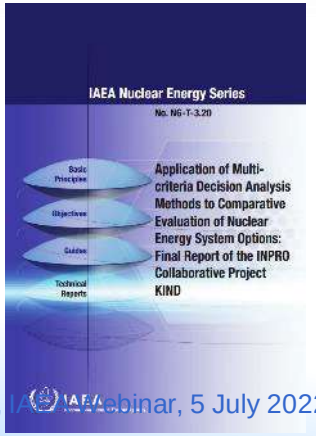
2016



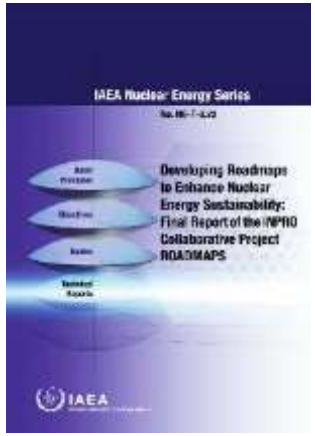
2018



2019



2021

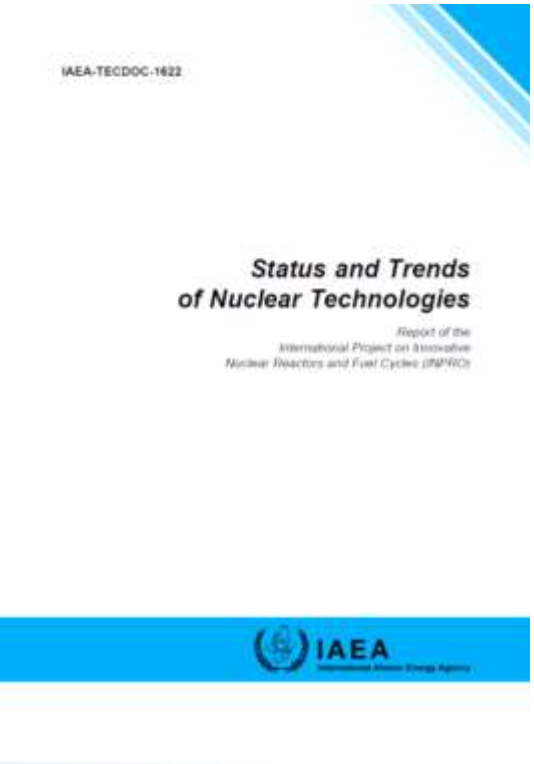


Innovative Multicomponent Nuclear Power systems in INPRO "history"

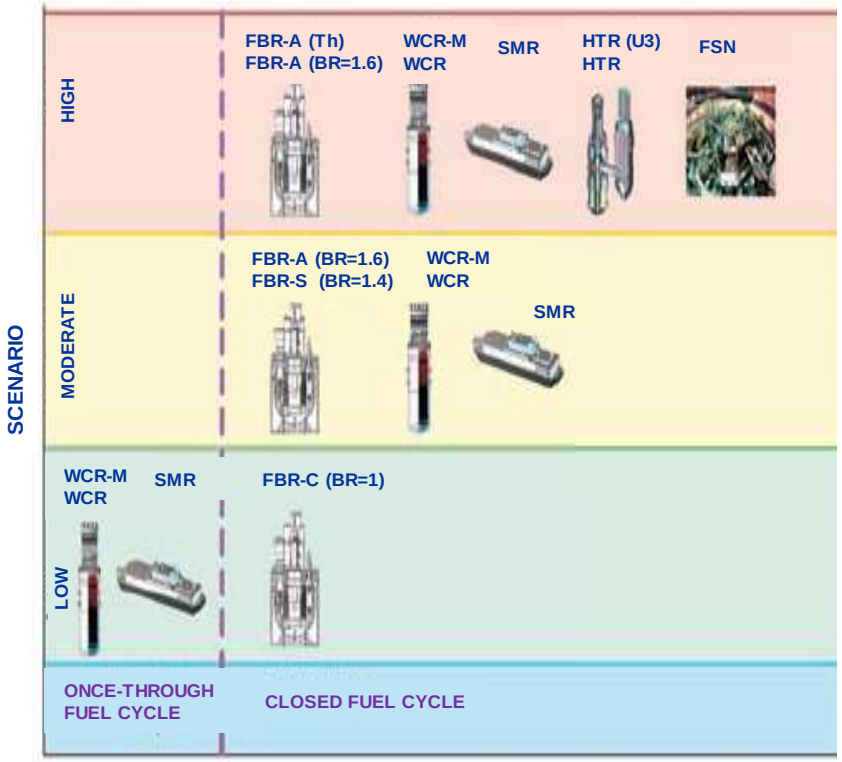
- **2000s: Evaluation and Assessment of nuclear reactor and fuel cycle innovative tendencies:**
  - **NESA for Closed Nuclear Fuel Cycle with Fast Reactors**
  - **Role of Thorium to Supplement Fuel Cycles of Future Nuclear Energy Systems**
    - **2010s: Strategic Studies and tools for consideration of international Nuclear Energy architecture and synergies (GAINS, SYNERGIES, ROADMAPS, KIND)**
      - **2020s: ASENES as full-scale Nuclear Power strategic service for MSs**
      - **New collaborative project: STEP FORWARD – ASENES for multicomponent NE systems with integrated fuel cycle**

INPRO's general overviews of innovative nuclear reactors and fuel cycle technologies in MSs

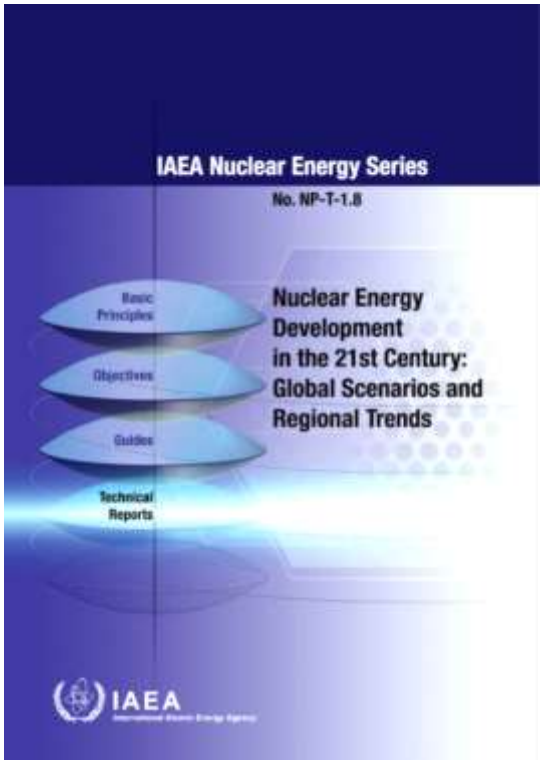
2009



Consideration of Future Nuclear Energy



2010



Assessment of NES based on a CNFC with FR – Joint Study

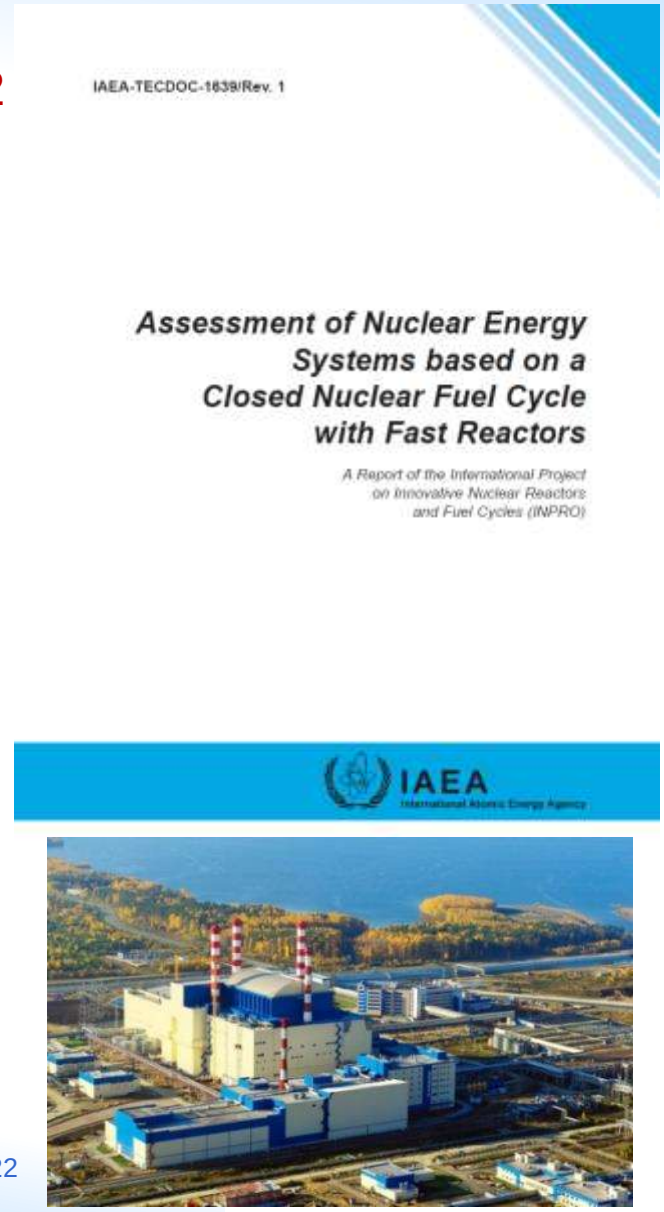
A Joint Study was started in 2005 and completed in 2007 within the INPRO.

Canada, China, France, India, Japan, the Republic of Korea, the Russian Federation, and Ukraine participated in this study.

The objectives were to assess a nuclear energy system based on a closed fuel cycle (CNFC) with fast reactors (FR) regarding - ***Sustainability, Determine milestones for the nuclear energy system deployment, and Establish frameworks for, and areas of, collaborative R&D work.***

The assessment was carried out in accordance with requirements of INPRO methodology and guiding documents of the Joint Study developed and approved by the participating parties.

2012



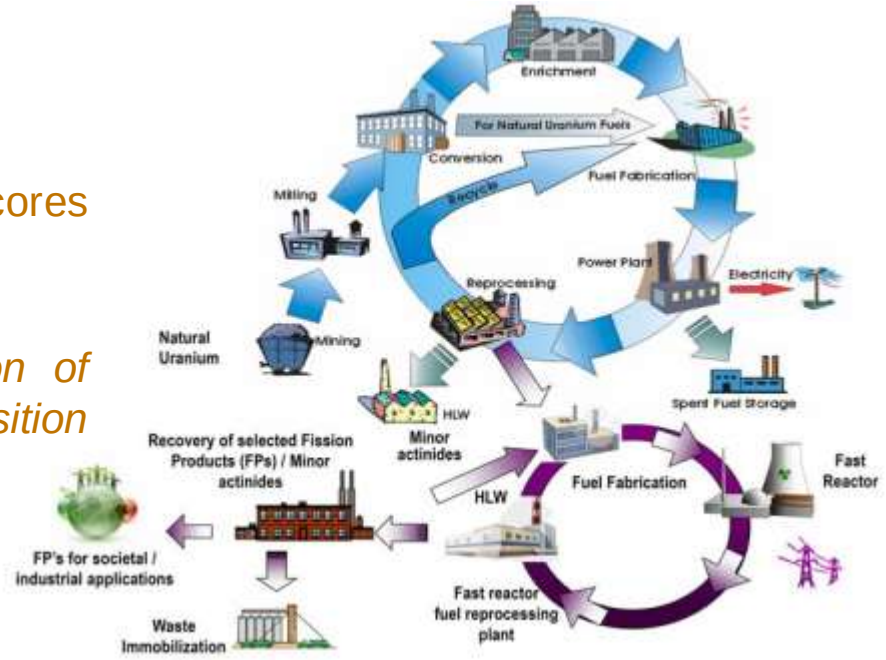
STEP FORWARD: new INPRO Pilot Study

Overall objective: to apply the ASENES package and national tools of relevance to evaluation of the nuclear energy systems and scenarios involving initially small number of innovative nuclear energy installations to enable multi-recycling of fuel in a complete nuclear energy system including also the operating and evolutionary reactors with thermal neutron spectrum.

The scope of innovative nuclear energy installations to be considered is open to include a variety of options, such as:

- ✓fast reactors with any types of coolant,
- ✓molten salt reactors,
- ✓accelerator driven subcritical systems,
- ✓thermal spectrum reactors with modified cores supporting fuel multi-recycling or even
- ✓fission-fusion hybrids.

Within studies on multi-recycling, *transmutation of radioactive waste and excess plutonium disposition* could also be topics for consideration.



Timeframe: 2022-2024

SMR and TNPP as institutional and technical innovations

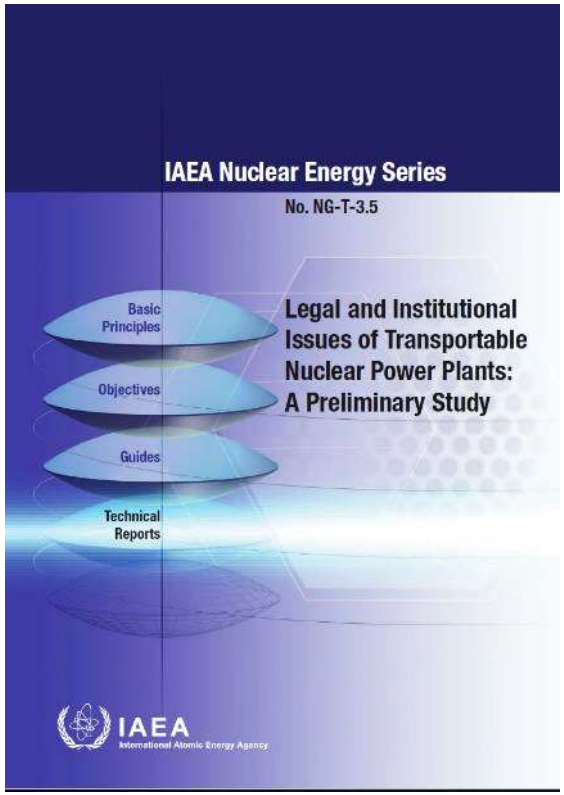
- **2000s-2010s – prospective role of SMRs. Overall considerations.**
  - **First studies of Transportable Nuclear Power Plants (TNPP) – finding of some legal gaps.**
  - **Request by MSs through GC resolutions to continue studies**
    - **2015- 2020 - Study of specific cases (TNPP 2)**
    - **Recommendation for further IAEA studies of the Legal aspects, Nuclear Safety and Security approaches and others**
      - **Current: Assessment and Strategy:**
      - **NESA for some SMRs designs**
      - **ASENES – SMR as new strategic service for MSs**

Studies on Transportable Nuclear Power Plants

- A preliminary study was performed in 2008-2013 and documented in the NE Energy Series Technical Report No. NG-T-3.5
- Following issues were considered: Infrastructure, safeguards, legal, nuclear safety and security, nuclear liability.

2013

- Collaborative Project: "INPRO Case study for the Deployment of a Factory Fuelled Small Modular Reactors (SMR)" – TNPP-2
- Three TNMPP have been selected for analysis:
  - (1) a submersible TNM(s);
  - (2) a floating TNM(s);
  - (3) a land-based TNM(s).
- TNM with reactors loaded with nuclear fuel in the Service Centre, tested and sealed in Supplier State for further relocation and operation a Host State.
- The study included a scenario of maximum outsourcing.



Collaborative Project TNPP-2

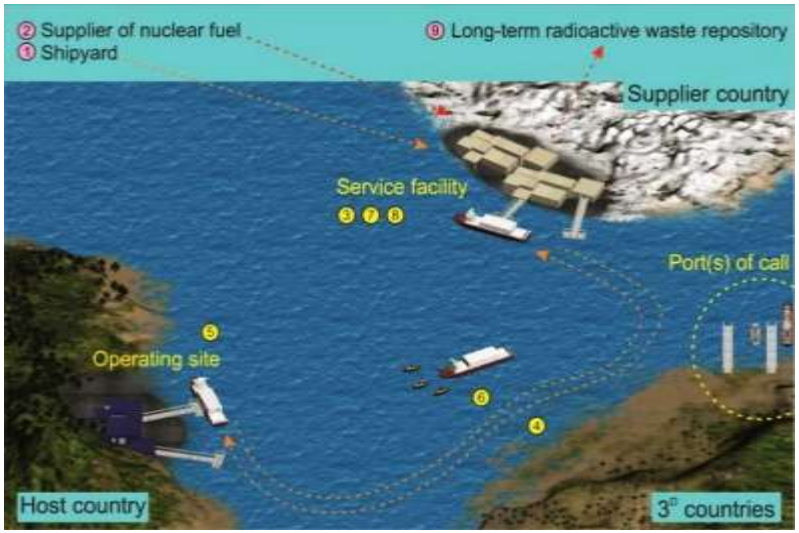
The preliminary conclusions:

1. Despite the absence of international rules specifically developed for a TNM/TNMPP, the **existing legal and regulatory framework** usually applied in large NPP projects is generally applicable for all stages of TNM/ TNMPP life cycle. The modifications of procedural solutions may be required for safeguards, civil liability for nuclear damage, etc.

2. The existing differences from conventional large NPPs with regard to the regulatory framework primarily related to **the marine specifics of a TNM** of both the floating and submersible designs, as well as the application of maritime law during TNM/TNMPP relocations between the Supplier State and the Host State. Also, innovative licensing mechanisms may be needed due to the transient nature of the TNMs.

3. The identified "gaps" in the legal framework of TNM/TNMPP at the current stage of technology development may be covered by **Intergovernmental Agreements** for the implementation of particular TNMPP projects.

4. **TNM Pilot Projects or FOAK** will bring new practical information for further deployment of TNM/TNMPP concept.



Current INPRO Projects on SMR

- **Case studies for the Deployment of Factory Fuelled SMRs (Transportable NPPs)**

- **Nuclear Energy system Sustainability Assessments (NESA) for** SMR initiated: Argentina (CAREM), Russia (RITM-200), ROK (SMART)

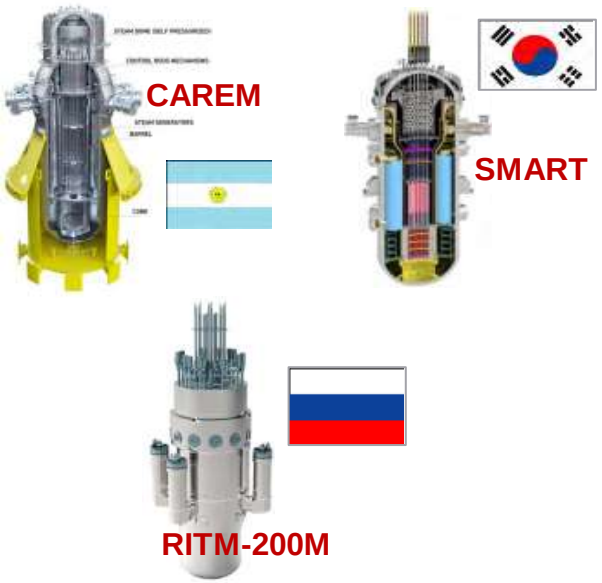
- **17th INPRO DF on Opportunities and Challenges in Small Modular Reactors /** 2–5 July 2019, Ulsan, Republic of Korea (143 participants from 22 Member States)

- **Collaborative project "Sustainable deployment scenarios for small modular reactors" (ASENES SMR)**

  Objective:

  - To provide the formulation and evaluation of promising scenarios and success factors for the deployment of sustainable NES with SMRs, including the prospective models of cooperation.

SMR NESA



Future technologies:
Fusion reactors in INPRO studies

INPRO Members regularly mentioned Fusion as advanced Power technology

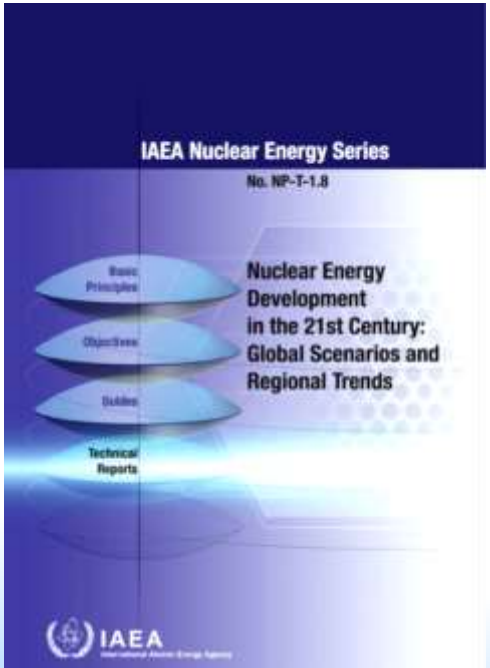
BUT:

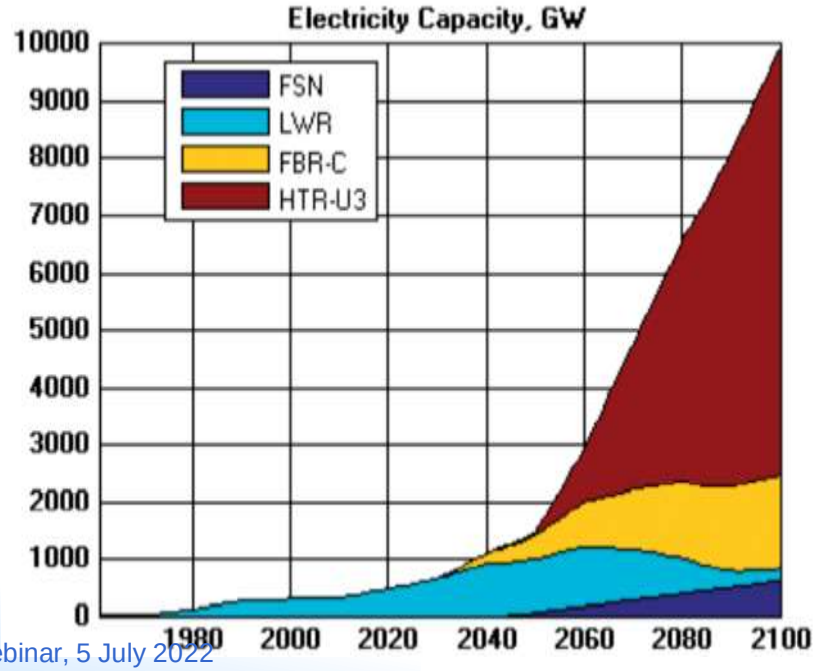
There were not enough the initial data on fusion (thermonuclear) power reactors for NESA fulfilment or for other INPRO assessments.

So the fusion power technology was not assessed by INPRO Methodology.

Fusion neutron sources were considered in INPRO Global Scenarios consideration (NP-T-1.8, 2010) as sources for breeding for advanced nuclear power systems based on Th/U-233 cycle

2010





New INPRO Study: Legal and Institutional Issues of prospective deployment of Fusion facilities

- **Expected frame of the Study (started on 2022 followed by INPRO MSs recommendation):**
  - Discussion on the long-term sustainability issues for prospective deployment of fusion based facilities with a focus on non-technical aspects (jointly with other IAEA Departments and Sections)
  - Consideration of INPRO methodology and approaches application for long-term sustainability assessment of innovative energy systems with fusion based facilities
  - Review of legal and institutional issues, factors, and challenges, then identify gaps considering the current international instruments and national nuclear legislation and regulations.
  - Identification of main drivers and impediments for fusion based facilities implementation

Institutional innovations: effect on "Nuclear Power Landscape"

- INPRO Methodology
  - Infrastructure (for first NPP)

→ **"Bright Future":**
Safer than previous
Better than previous
Economically acceptable
Environmentally friendly

- Reconsideration of Supplier and Host States roles / Newcomers and their responsibility

→ New cooperation approaches

- Legal/Institutional innovations

→ Framework for cooperation and
vision beyond 50 years

Conclusions:

INPRO methodology and INPRO tools are valid instruments for:

- **Strategic planning of Nuclear power Systems for MSs with enhanced international and regional cooperation**
- **Systematic promotion of nuclear innovations and understanding of their roles in sustainable development**

IAEA
International Atomic Energy Agency

Thank you for your attention

Nuclear energy development strategies and role of innovations

Alexander BYCHKOV
Senior expert in INPRO

“How the IAEA helps ensure that nuclear energy is sustainable” – the key takeaways

- The overall objective of INPRO is to help ensure that nuclear energy is available to contribute, in a sustainable manner, to the growing energy needs of the current century and beyond

- INPRO is forward-looking and assists Member States in developing sustainable, long-range national nuclear energy using a holistic approach that includes application of the INPRO Methodology, analytical frameworks and tools

- INPRO investigates and promotes the innovative nuclear energy technologies and institutional arrangements that support development of sustainable nuclear energy

Questions and Answers

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INPRO Collaboration Platform: nucleus.iaea.org/sites/inpro/