INPRO
International Project on
Innovative Nuclear Reactors
and Fuel Cycles

Fusion reactors in INPRO strategic studies and new INPRO collaborative project on the “Legal and Institutional Issues of prospective deployment of Fusion facilities”

Technical Meeting on Synergies Between Nuclear Fusion Technology Developments and Advanced Nuclear Fission Technologies

6-10 June, 2022, Vienna, Austria,

Alexander Bychkov, Mikhail Khoroshev, Brian Boyer, Hussam Khartabil
NENP INPRO Section

Where is INPRO Innovation?

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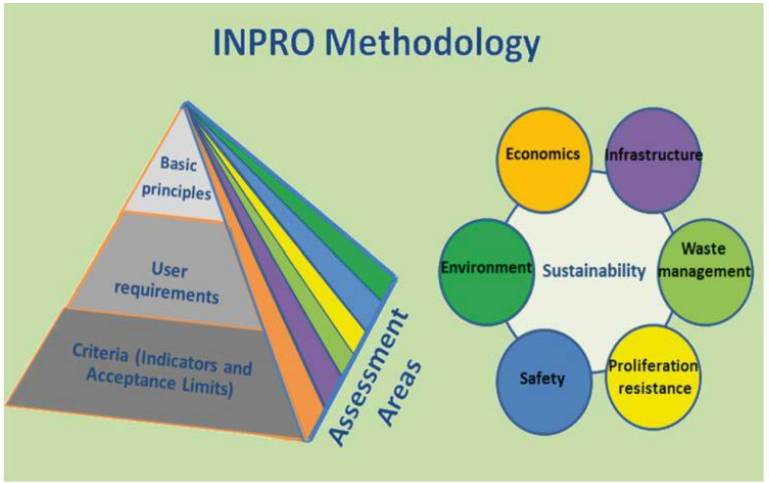
In connection with the Fusion Subject

INPRO Methodology Key Areas

- **Innovation in the areas of**
  - **Reactors**
  - **Nuclear fuel cycles – front-end and back-end**
  - **Institutional approaches to nuclear power**
  - **Sustainable development**
  - **National strategic and long-term planning**
  - **Develop and provide tools and services**
  - **Partnerships for Nuclear Futures**

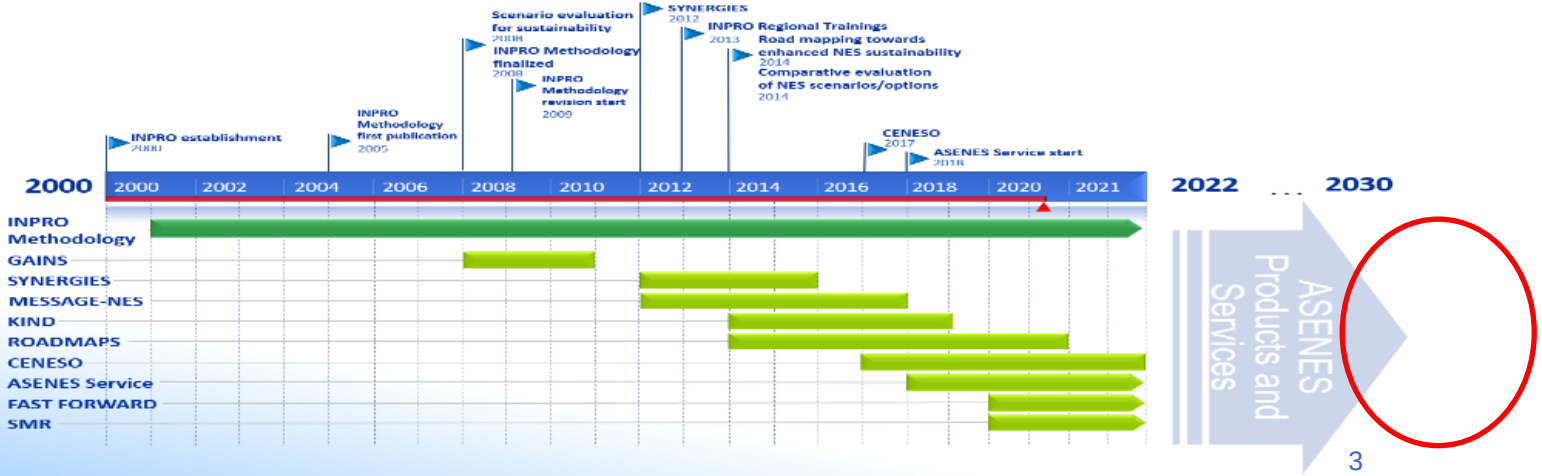
Holistic Approach to Assess Nuclear Energy Systems in 6 Areas to Assure Sustainability



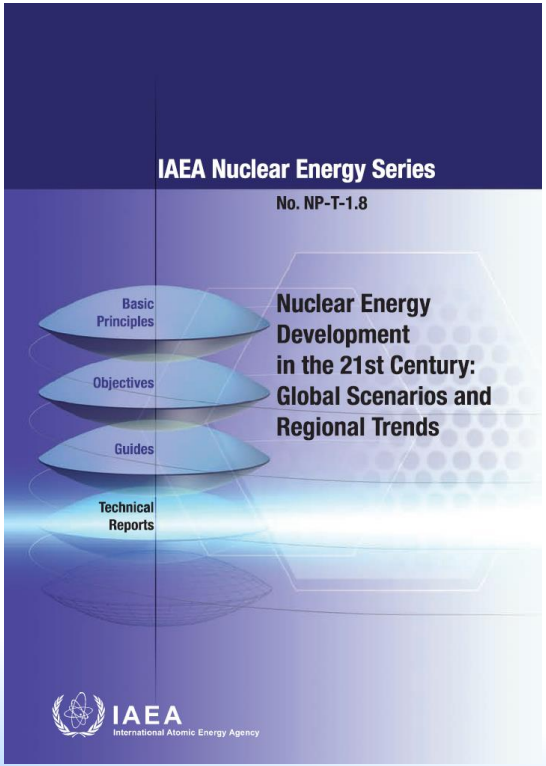
INPRO Task 1:Global Scenarios

Needs of the fusion power technology analysis.

- 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** – and its application for SMR and multi-recycling – Key New Tasks



Fusion reactors in past 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

Fusion in INPRO studies (NP-T-1.8)

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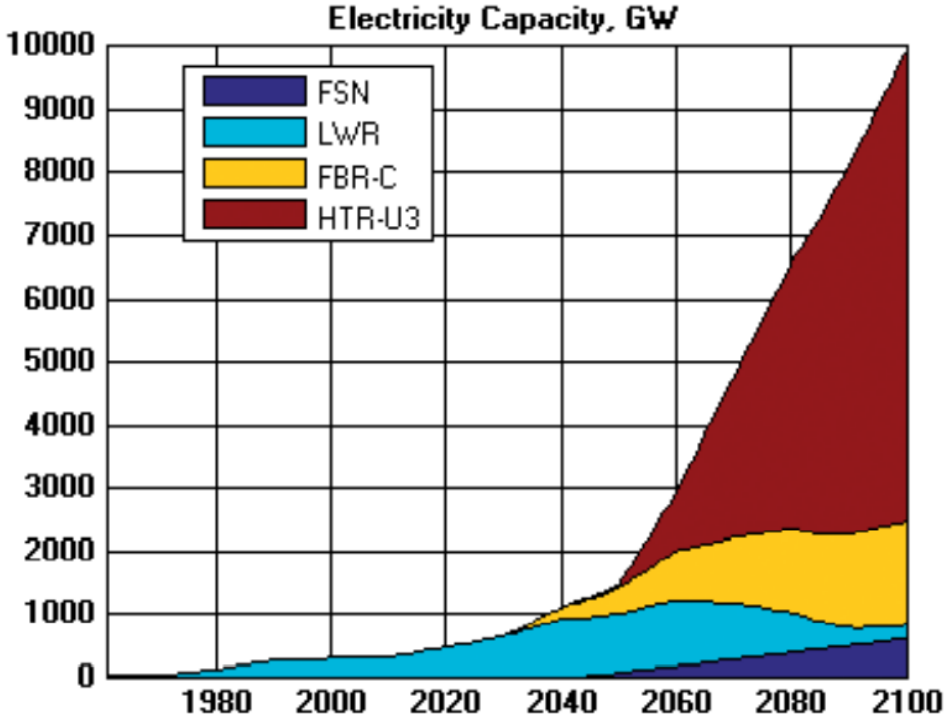
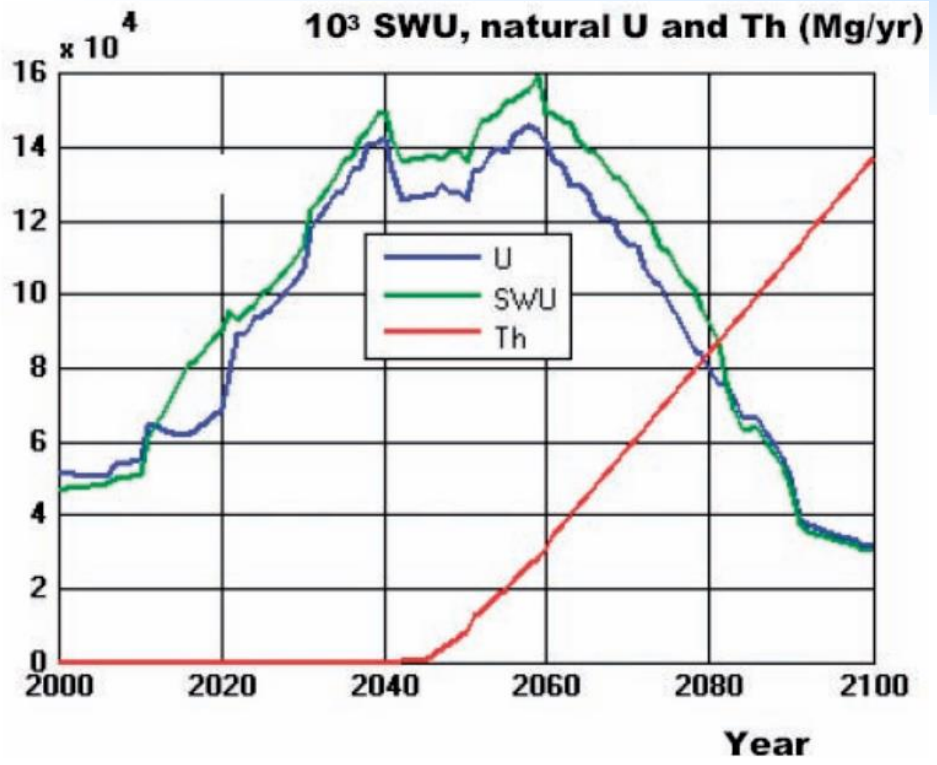
"The use of Fusion Neutron Sources for breeding"

- A Fusion Neutron Source (FNS) would be an essential element of a nuclear energy system, where the FNS is used for U-233 breeding in liquid Th fuel blankets (molten salt) with deeply suppressed fission
- In a hybrid fusion-fission system the power of the fusion reactor can be relatively small, Since the share of fusion neutron sources in the system would be small (below 10%), they could be built in a limited number of countries, for instance, countries hosting international/multinational fuel cycle centres.



Fusion in INPRO studies (NP-T-1.8)

- The structure of nuclear energy systems with fusion reactors used for fissile breeding would be qualitatively different from systems based on the large scale deployment of fission breeder reactors.
- As a recommendation for the future actions, it was proposed to further study the ideas about international cooperation.
- **The potential use of fusion reactors for the breeding of fissile material for fission reactors has been examined. Such a synergistic fusion-fission nuclear energy system has not been considered in detail in this study but may have potential advantages and such a nuclear energy system may be considered in more detail in a future study.**



INPRO's Global scenarios - GAINS

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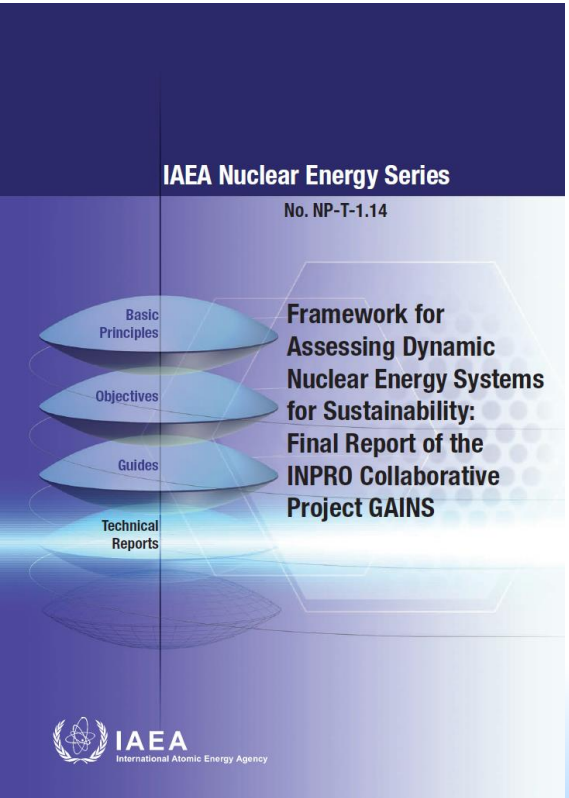
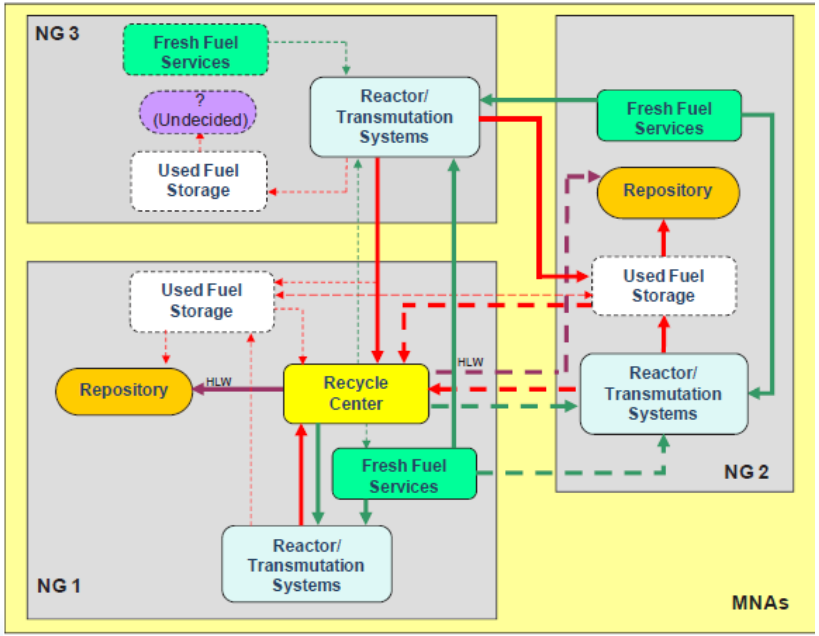
INPRO Global Sceneries Studies as usual had time-line in 40-50 years.
It is short term for Fusion Power deployment.
But the key approaches could be applied.

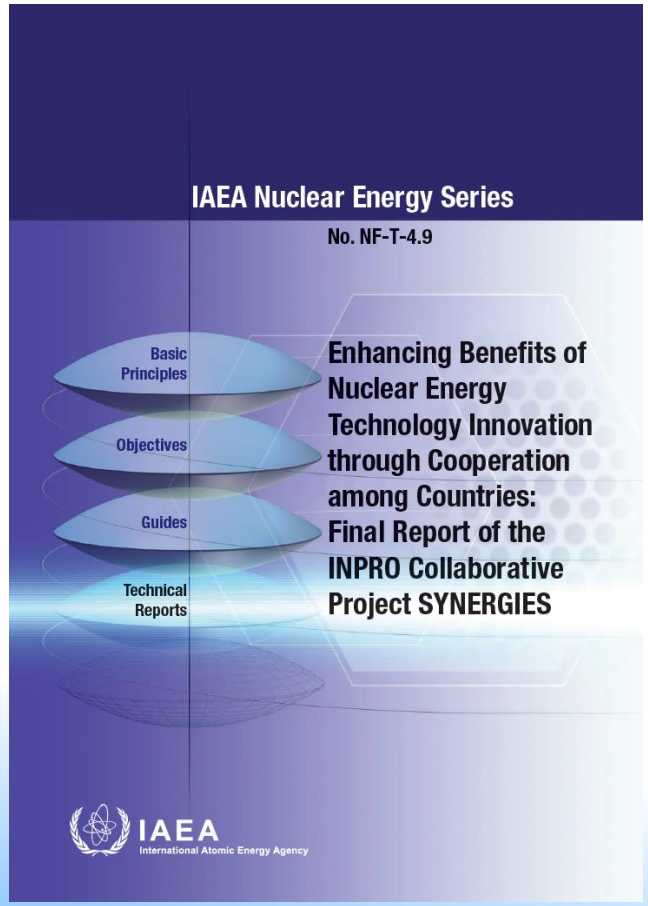


Fusion can change Nuclear power "international architecture":

- Resources
- Raditoxisity of wastes
- "transmutation" of fission tails



INPRO's Global scenarios - SYNERGIES



2015 — 2025 — 2035 — 2050 — Fusion deployment

Technologies off the shelf

Synergistic solutions
- Shared nuclear power plant (investment)
- Shared capabilities and resources
- Front end
  - Multi-national facilities (URENCO, Angarsk)
  - Fuel Bank
  - MOX/100% MOX/TOP MOX/ERU & precycling schemes
- Back end
  - Recycling services
  - (Regional) interim storage solutions
- Nuclear power plants
  - LWR/PHWR

Result of today's R&D

Additional synergistic solutions:
- Front end
  - Additional multinational facilities
  - New fuels ('dense', metal, nitride, thorium, TRISO) opening additional options
  - Fuel leasing
- Back end
  - Additional regional recycling services (China, India Japan, Russian Federation)
  - Multirecycling of plutonium in LWRs
  - Regional interim storage solutions
  - (Regional) geological disposal sites deployment
- Nuclear power plants
  - ALWRs/AHWRs
  - (Oxide fuel) FRs
  - SMRs/HTRs

Fruits of tomorrow's R&D

Additional synergistic solutions
- Front end
  - Thorium/^{233}U cycle deployment
- Back end
  - Additional regional recycling service
  - Advanced reprocessing technologies (P&T, pyro)
- Nuclear power plants
  - Proven F(B)R and deployment
  - Maturing symbiotic nuclear power plant parks with integrated fuel cycle schemes

INPRO Global Sceneries Studies as usual had time-line in 40-50 years.

Fusion Strategy as power source should be considered in line with other innovations in energy supply.

Options for possible INPRO studies

Analysis of Legal and Institutional aspects

Nuclear Energy System Assessment (NESA) or limited NESA

Case Studies based on INPRO Methodology

Examples: INPRO Studies on legal and institutional issues

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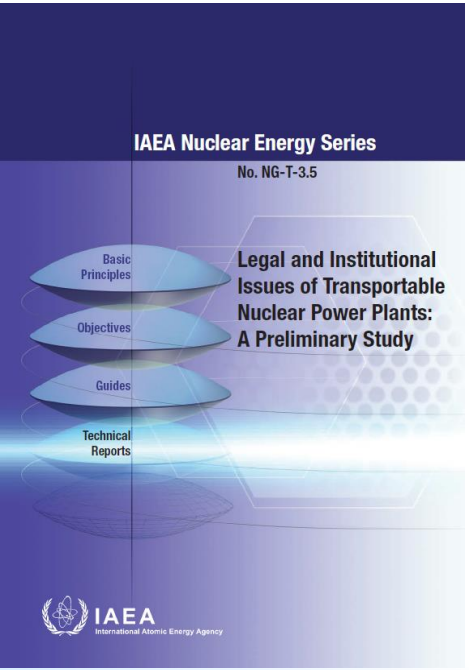


As example: 2007-2013:

INPRO Members performed collaborative project: **Legal and Institutional Issues of Transportable Nuclear Power Plants: A Preliminary Study** (IAEA Nuclear Energy Series No. NG-T-3.5, 2013).

The similar INPRO study related the Back-End of NFC close to publishing

IAEA TECDOC

Cooperative Approaches to the Back End of the Nuclear Fuel Cycle: Drivers and Institutional, Economic and Legal Impediments

Draft

International Atomic Energy Agency
Vienna, XXXX

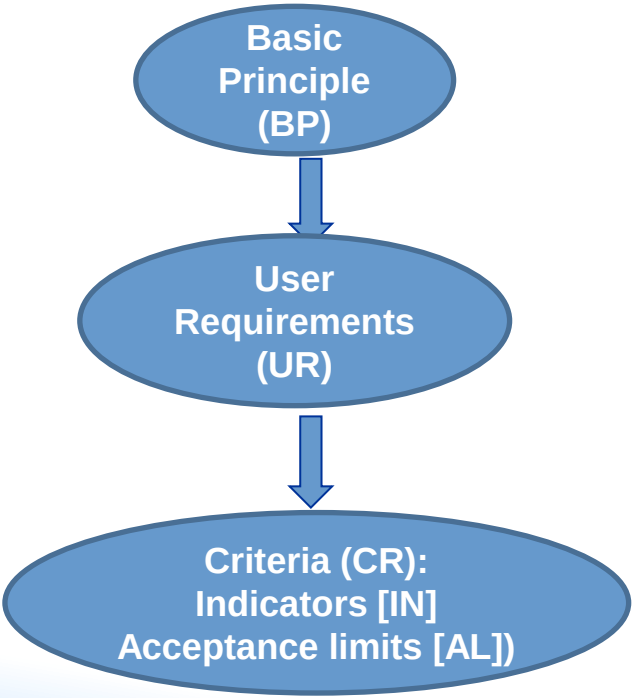
Composition of TNPP Report: Legal and Institutional Issues of Transportable Nuclear Power Plants: A Preliminary Study

- Reference cases
- Infrastructure issues (based on “Milestones approach”)
- Safeguards issues
- Legal issues (for some scenarios, for supplier and host states, for other states and international community)
- Specific issues relating to nuclear safety and radiation protection
- Specific legal issues relating to nuclear security
- Specific legal issues relating to nuclear liability
- Summary of legal and institutional challenges

The report was important for further understanding in area of SMR and TNPP:

- **Identified ‘gaps’ in legal aspects, approaches to safety analysis and licensing**
- **MSs requested to continue studies reflected in GC resolutions on NS and NE**

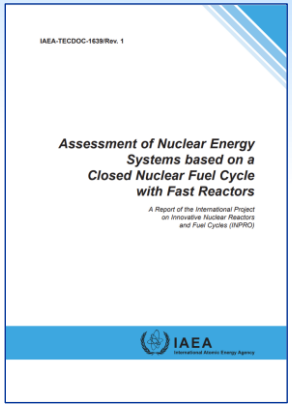
Case Studies based on INPRO Methodology

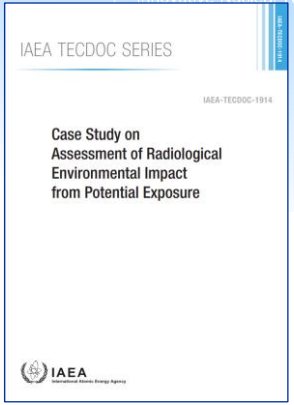


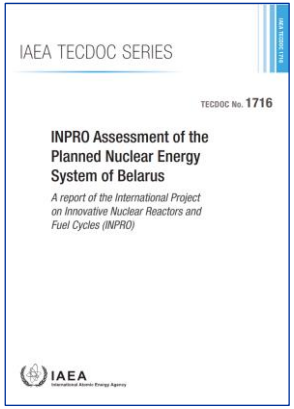
Goals for development of sustainable NES (Nuclear Energy System)

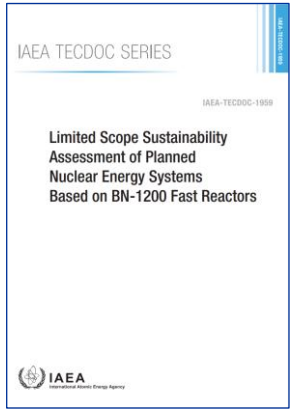
Requirements for designer, operator, industry and/or State to meet goal defined in Basic Principle (BP)

Assessor's tools to check whether NES meets User Requirement (UR)









INPRO MSs fulfilled a number of the Case Studies and NESAs

INPRO Nuclear Energy System Assessment Structure

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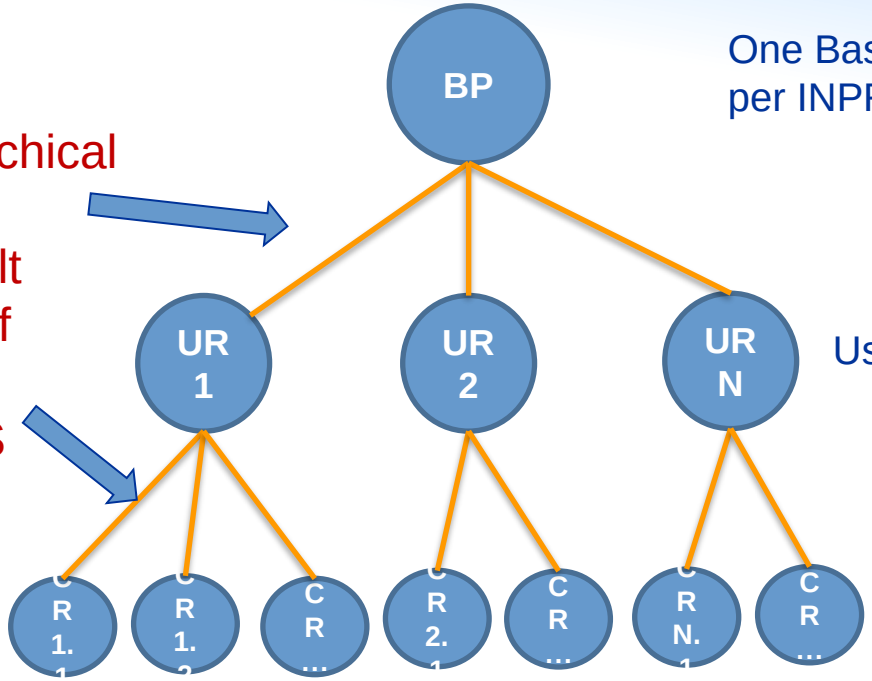
The hierarchical analysis could result a finding of "gaps" in the NES



One Basic Principle (BP) per INPRO area

User Requirements (UR): 2-7

Criteria: Indicators (IN) + Assessment Limits (AL),

Result of the assessment: Sustainability of a nuclear energy system
It is possible to apply for fusion nuclear power technology

Decision of INPRO Steering Committee

- Last (30th) INPRO SC meeting was held on 18-21 October 2021
- Based on earlier recommendation of INPRO MSs, GC resolutions and SAGNE recommendations, 30th SC meeting approved start of new activity for next period: **Legal and Institutional Issues of prospective deployment of Thermonuclear (Fusion) facilities**
- The title was changed after Kick-off meeting
- The implementation of this collaborative project "**INPRO Study on Legal and Institutional Issues of Prospective Deployment of Fusion Facilities**". will be an activity under Task 2 "Innovations" in Project 1000151 of the IAEA Programme & Budget 2022 – 2024.

TASK 2 INPRO:
New Activity Proposal for 2022-23

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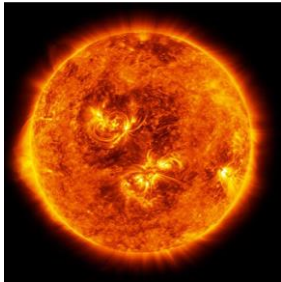
Legal and Institutional Issues of prospective deployment of Thermonuclear facilities: Preliminary study. Possible scope includes:

- Identify the area of thermonuclear reactors (TNR) implementation (jointly with NPTDS and other groups)
- Examine expected legal and institutional issues and challenges especially in the field of current international nuclear legislation, nuclear safety and security, non-proliferation and analyse them based on limited a NESA-approach
- Identification of main drivers and impediments for TNR implementation
- Expected IAEA Participants: NE (INPRO, NPTDS, PESS, WTS), NA (NANS), NS (NSNI, NSFW, NSNS), SG (SGCP), OLA

Basis for Term of Reference

- Requests of MSs to prepare overall landscape of non-technical issues related fusion power technology implementation.
- Avoid overlapping:
  - NE/NPTDS – all technical aspects as nuclear power systems
  - NA/NAPC – scientific aspects and R&D
  - NS/NSNI – licensing current status but future needs for energy sources on the basis of fusion – industrial
  - OLA – legal aspects, conventions, risks, conventional view on future expanding
  - INPRO – strategic analysis on non-technical aspects
- Availability of information and data for analysis



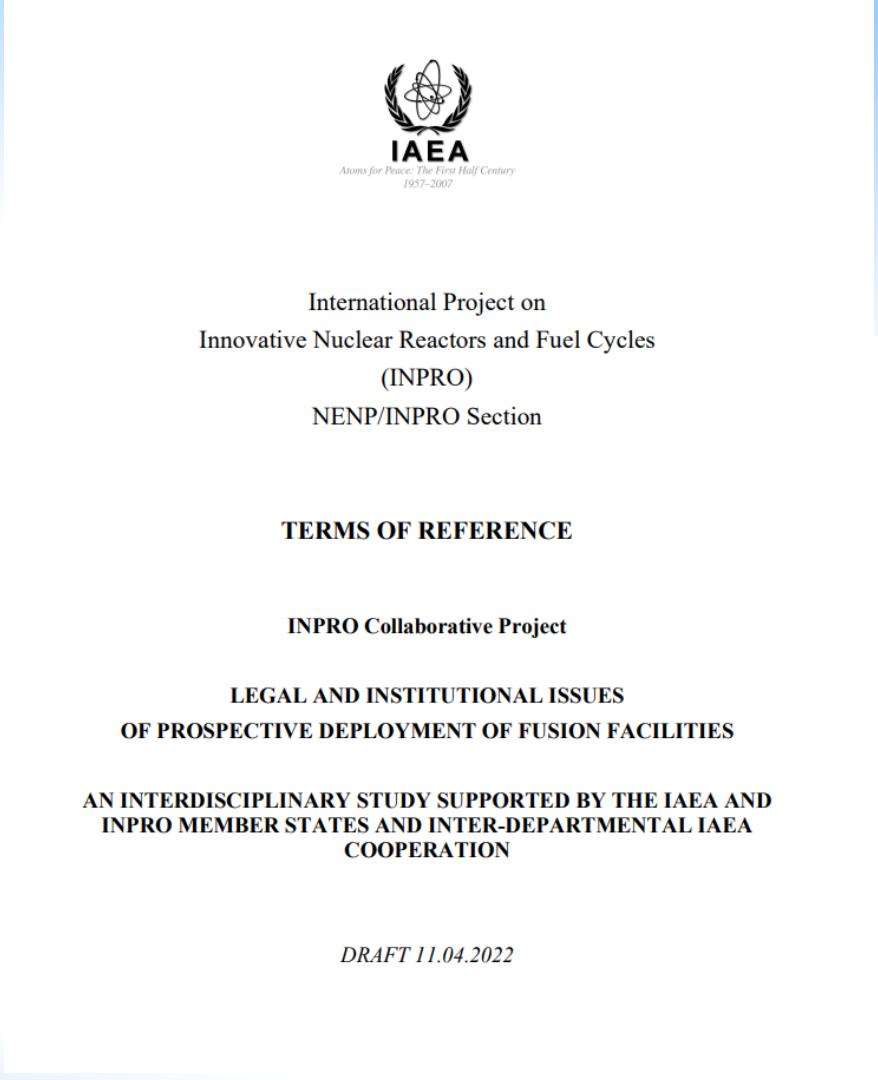
Kick-off meeting to develop Terms of Reference for the INPRO study on Legal and Institutional Issues of prospective deployment of Thermonuclear (Fusion) facilities

Virtual Event, Vienna, Austria

28.02.2022–03.03.2022

The sessions of Kick-off meeting:

- Legal issues and challenges and challenges
- Divers and impediments to fusion implementation.
- Synergies between fission and fusion energy systems (non-technical aspects)
- Long-term sustainability issues beyond fusion's technical aspects.



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Atoms for Peace: The First Half Century
1957–2007

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

TERMS OF REFERENCE

INPRO Collaborative Project

LEGAL AND INSTITUTIONAL ISSUES
OF PROSPECTIVE DEPLOYMENT OF FUSION FACILITIES

AN INTERDISCIPLINARY STUDY SUPPORTED BY THE IAEA AND INPRO MEMBER STATES AND INTER-DEPARTMENTAL IAEA COOPERATION

DRAFT 11.04.2022

OVERALL OBJECTIVE OF THE STUDY

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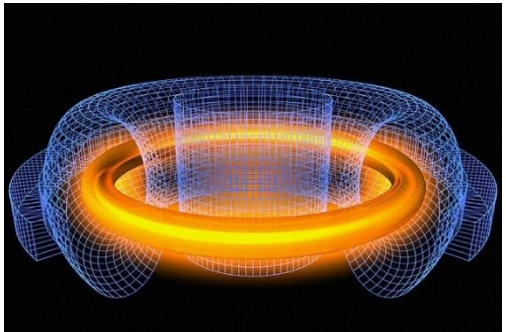
The overall objective of the INPRO study on “Legal and Institutional Issues of Prospective Deployment of Fusion Facilities” is to support the fusion community in its effort to accelerate the development and implementation of fusion facilities, integrated fusion-fission systems, and other innovative energy systems within the next decades, with the early identification of possible gaps in long-term sustainability.

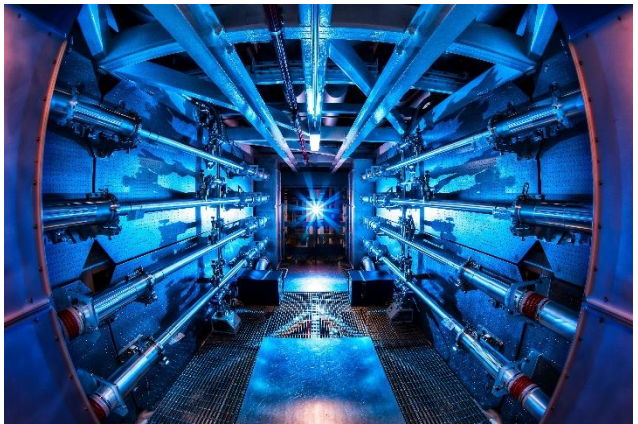
Achievement of the overall objective will be through cooperative work on cross cutting issues performed by the IAEA and INPRO Member States along with inter-departmental IAEA cooperation.



SPECIFIC OBJECTIVES (1)

IAEA INPRO International Project on Innovative Nuclear Reactors and Fuel Cycles

- Discuss the long-term sustainability issues for prospective deployment of fusion facilities with a focus on non-technical aspects.
- Consider application of INPRO methodology and approaches for long-term sustainability assessment of overall elements of innovative energy systems with fusion facilities.
- Review legal and institutional issues, factors and challenges, then identify gaps considering the current international instruments and national nuclear legislation. The review will include the following aspects of fusion related
  - Regulatory framework
  - Nuclear safety and licensing
  - Legal aspects including liability
  - Nuclear security issues
  - Safeguards and non-proliferation issues
  - Key export/import concerns
  - Comprehensive infrastructure issues



SPECIFIC OBJECTIVES (2)

INPRO
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Identify the main drivers and impediments to the implementation of fusion facilities:

- Economics
- Fusion potential for nuclear waste transmutation
- Manufacturing scale-up and “Gigafactory” production of fusion devices
- Need to address climate change
- Capacity building
- Human resources development
- Licensing timelines
- Insurance challenge

This INPRO study will coordinate with the following IAEA ongoing technical work (avoiding duplication and ensuring one-house approach):

- Technological synergies between fission and fusion (NENP)
- Technical definition of fusion facilities and classification (NS/NA/OLA)
- Technical document on regulations for fusion facilities (NS/NA/OLA)
- Applicability of safety standards to fusion facilities (NS/NA)
- Market analysis on enabling technologies for fusion (NA)

Milestones and duration of the INPRO Fusion collaborative project (2022-2024)

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Activity	Status	Output
2022– Kick-off Consultants' Meeting	Convened on 28.02-03.03.2022	Draft Terms of Reference, preliminary scope of work
2022 – Participation in Technical Meeting on Synergies between Nuclear Fusion and Fission…		New INPRO collaborative project announcement. Individual presentations of the project participants. Clarification of the draft TOR.
	Current Technical Meeting, 6-10 June 2022	
2022 –Consultants' meeting	September 19-23, 2022	Approved Terms of reference, Work plan and schedule with responsibilities, initial results
2023 – INPRO Technical meeting	Considered - 1st quarter 2023	Review of intermediate results, path forward
2023 –Consultants' meeting	Considered	Review of the final draft of the TECDOC
2023–Preparation of final draft NES/TECDOC for publication, consultants' meeting	Considered	Draft TECDOC editing and submission of the final draft to NE DCT (for internal review), then to Publications Committee

Beyond of IAEA programs but useful for current study

- Evaluation of risks for new power technologies
- Evolution of electro/power market and demands/supplies
- Progress in the systems for the energy accumulation and efficiency growth
- Possible new aspects for special materials supply and technological breakthroughs

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Thank you!