INTERNATIONAL PROJECT ON INNOVATIVE NUCLEAR REACTORS AND FUEL CYCLES (INPRO)

GLOBAL NUCLEAR ENERGY SCENARIOS

Transition to Sustainable Nuclear Energy Systems and Building Regional Cooperation

INPRO Collaborative Projects GAINS, SYNERGIES & ROADMAPS, and Results from the 4th INPRO Dialogue Forum, IAEA, July 2012

Presented by Vladimir KUZNETSOV

INPRO GC56 Side Event "Enhancing Global Nuclear Energy Sustainability: Briefing on the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)"

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INPRO Project 2: GLOBAL NUCLEAR ENERGY SCENARIOS

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Objective:

- To develop global and regional nuclear energy scenarios, on the basis of a scientific-technical analysis, that lead to a global vision on sustainable nuclear energy development during the 21st century.

Project 2: GLOBAL NUCLEAR ENERGY SCENARIOS

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- Project 2 helps participating countries define *realistic* long-term national energy strategies by providing a framework for the analysis and assessment of :
  - how to make a transition from the current fleet of reactors and nuclear fuel cycles to more sustainable nuclear energy systems
  - how national energy systems could contribute to, and benefit from, sustainability of a regional and global nuclear energy system
  - the role of collaboration with other countries on the way to sustainable nuclear energy systems
  - 'win-win' strategies for collaboration between suppliers and users on the way to sustainable nuclear energy systems

INPRO Collaborative Projects GAINS, SYNERGIES and ROADMAPS

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- Predecessor:
  - Collaborative project GAINS (Global Architectures of Innovative Nuclear Energy Systems with Thermal and Fast Reactors and Closed Nuclear Fuel Cycle) (2008-2011)
- On-going activity:
  - Collaborative Project SYNERGIES *(Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability)* (2011–2014)
- Future activity:
  - ROADMAPS for a transition to globally sustainable nuclear energy systems (2013–2015)

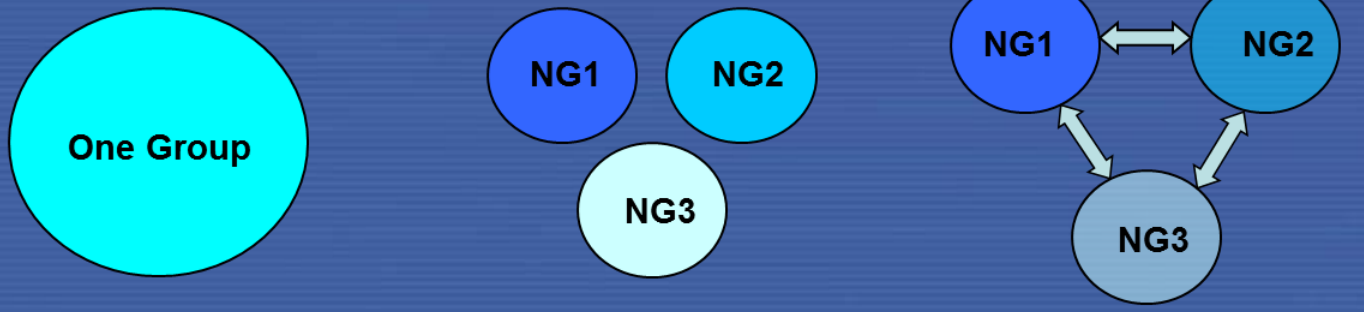
Collaborative Project GAINS

- Collaborative project GAINS (2008-2011), Final project report approved for publication
- (IAEA Publications Committee PC/MINS/480 of 2012-08-15)

  - Developed an internationally verified framework for the assessment of transition scenarios to future sustainable nuclear energy systems based on thermal and fast reactors and closed nuclear fuel cycle (approach, assumptions, scenarios, codes, data)
  - Considered heterogeneous world model and introduced a notion of non-personified groups of countries with different policy regarding nuclear fuel cycle (NG1, NG2, NG3)
  - Introduced “Key indicators” and “Evaluation parameters” to assess whether NES evolution scenarios lead to sustainable nuclear energy systems *(natural uranium & thorium resources, spent nuclear fuel accumulation, fissile material inventories, economics)*

Collaborative project GAINS

Collaborative project GAINS (2008-2011)



(a) Homogeneous

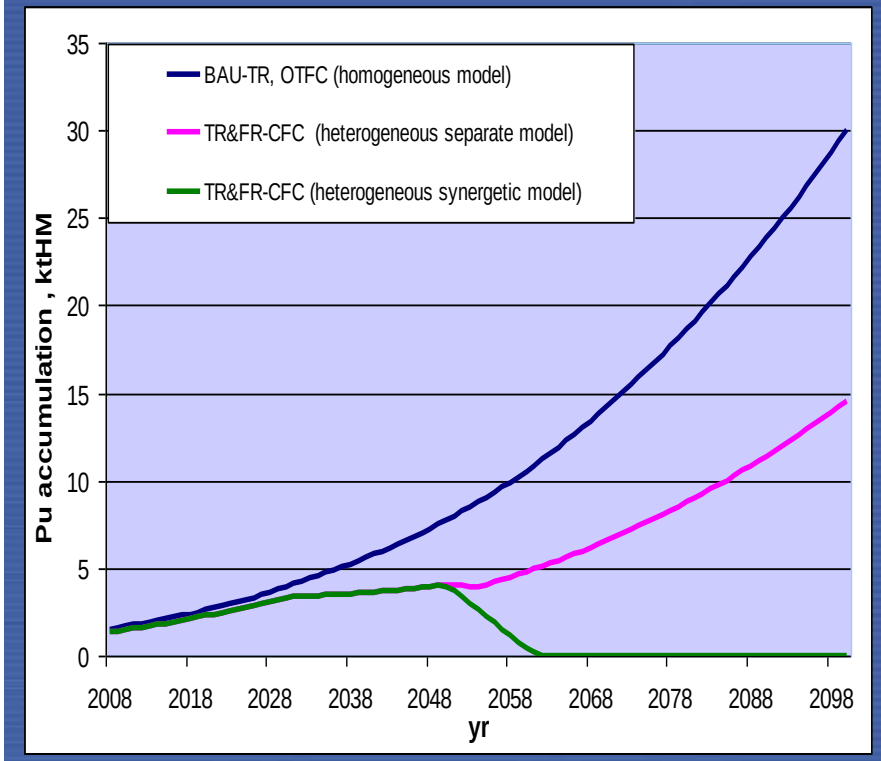
(b1) Heterogeneous Non-Synergistic

(b2) Heterogeneous Synergistic

- Most analyses treat world as single technology group
  - Assumes all follow the same strategy and use the same facilities
- GAINS Framework also supports breaking world into three separate nuclear strategy groups following different fuel cycle strategies
  - NG1 starts with LWRs, transitions to a closed fuel cycle with fast reactors
  - NG2 maintains an open fuel cycle with LWRs and HWRs
  - NG2 starts with no reactors, develops LWRs & minimal fuel cycle infrastructure

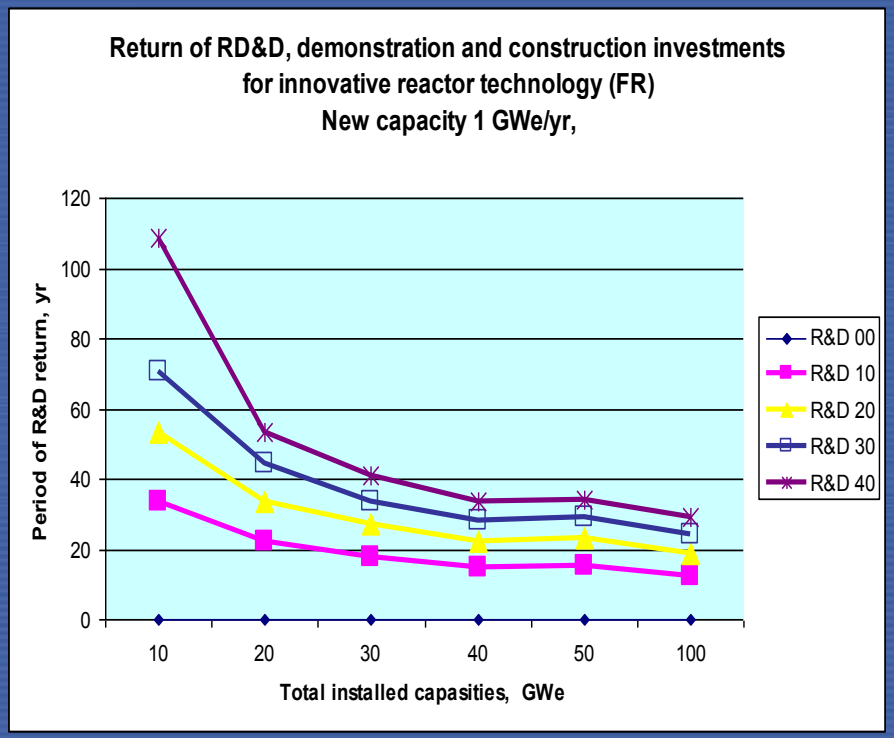
GAINS: Excerpt from the Conclusions

- Implementation of once-through global nuclear fuel cycle would result in a progressive **increase of SNF & Pu accumulation** *(blue line in the figure)*
- A non-synergistic global model when **SNF & Pu** are being used in TR & FR (BR=1.16) of NG1 only provides a **reduction of the accumulation rate but does not solve the problem completely** *(red line in the figure)*
- A synergistic model of the global NES (BR<1.16) gives an opportunity to **reduce SNF & Pu accumulation to a minimal stock for operational needs** and, thus, to provide their effective management (*green line in the figure*)



GAINS: Excerpt from the Conclusions

- The synergistic global nuclear fuel cycle gives an opportunity to NG2 and NG 3 countries, especially newcomers (NG3), to reduce their investments in introduction and deployment of national NES
- Providers of nuclear fuel cycle services expand markets and facilitate early return of R&D investments
- All win from the economies of scale



Collaborative project GAINS

- Collaborative project GAINS (2008-2011)
- - Examined possible scenarios with collaboration among different groups of countries and outlined possible benefits and issues of such collaboration
- - Concluded that sustainability of a Global NES in the 21st would be easier to achieve if technology holders and technology users collaborate in the back-end of the nuclear fuel cycle
- - Next logical step was to touch upon drivers and impediments for collaboration and to identify 'win-win' strategies for collaboration among technology holders and users (SYNERGIES project)
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Collaborative Project SYNERGIES

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INPRO
International Project on Innovative Nuclear Reactors and Fuel Cycles

- Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability
- Duration: 2011–2014
- Objectives:
  - To identify and evaluate mutually beneficial collaborative architectures and the driving forces and impediments for achieving globally sustainable nuclear energy systems
  - To identify short-term and medium-term collaborative actions capable to develop pathways to long-term sustainability.
- Deliverable: IAEA report in 2014
- IAEA-internal coordination: INIG, NPTDS, NEFW, PESS, NS, TC as appropriate

Collaborative project SYNERGIES

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- Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability

- Preparatory meeting convened in October 2011, Terms of reference developed
- Implementation endorsed by the participants of the 18th and 19th INPRO Steering Committee meetings in November 2011 and July 2012
- Kick-off technical meeting convened in June 2012 with 28 participants from 21 Member States, Implementation plan developed
- Algeria, Armenia, Belarus, Belgium, Bulgaria, Canada, China, Egypt, France, India, Indonesia, Israel, Italy, Japan, Republic of Korea, Malaysia, OECD-NEA, Pakistan, Poland, Romania, Russian Federation, Spain, Ukraine, USA and Vietnam have confirmed their interest to be participants or observers in the project, several other Members are considering their participation.
- Next meeting scheduled for 12-16 November 2012, in Vienna

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•Participants of the SYNERGIES Kick-off technical meeting of 4-8 June 2012

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SYNERGIES Structure

Task 1 (Core Task). Evaluation of Synergistic Collaborative Scenarios of Fuel Cycle Infrastructure Development

Task 4 (Cross-cutting Task). Elaboration of key indicators specific for synergistic collaboration, including economic assessment methods

Task 2 (Support Task). Evaluation of Additional Options for NES with Thermal and Fast Reactors

Task 3 (Support Task). Evaluation of Options for Minor Actinide Management

SYNERGIES: Expected Outputs

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- SYNERGIES is deemed to support development of comprehensive national nuclear energy strategies regarding international collaboration to achieve sustainable national, regional and global NES.

- In particular, SYNERGIES will help:

➢ define attractive innovative fuel cycle options possible at a regional level and promote an improved understanding of associated front-end and back-end regional interactions

➢ identify technical and institutional gaps that still need to be addressed within the specific future projects

- Next logical step would be to identify *"who could do what where and when"* to achieve sustainable NES

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- Future activity: ROADMAPS for a transition to globally sustainable nuclear energy systems (2013–2015)

Roadmap – flowchart of structured sets of actions, scope of work and timeframes for particular stakeholders in a collaborative scenario of transition to sustainable NES *(who does what where when)*

- This "umbrella" activity will integrate the outputs of a number of INPRO and IAEA projects to develop roadmaps for a transition to globally sustainable NES

- "What if" approach will be used to produce a number of variants

- Roadmaps could be updated on a periodic basis

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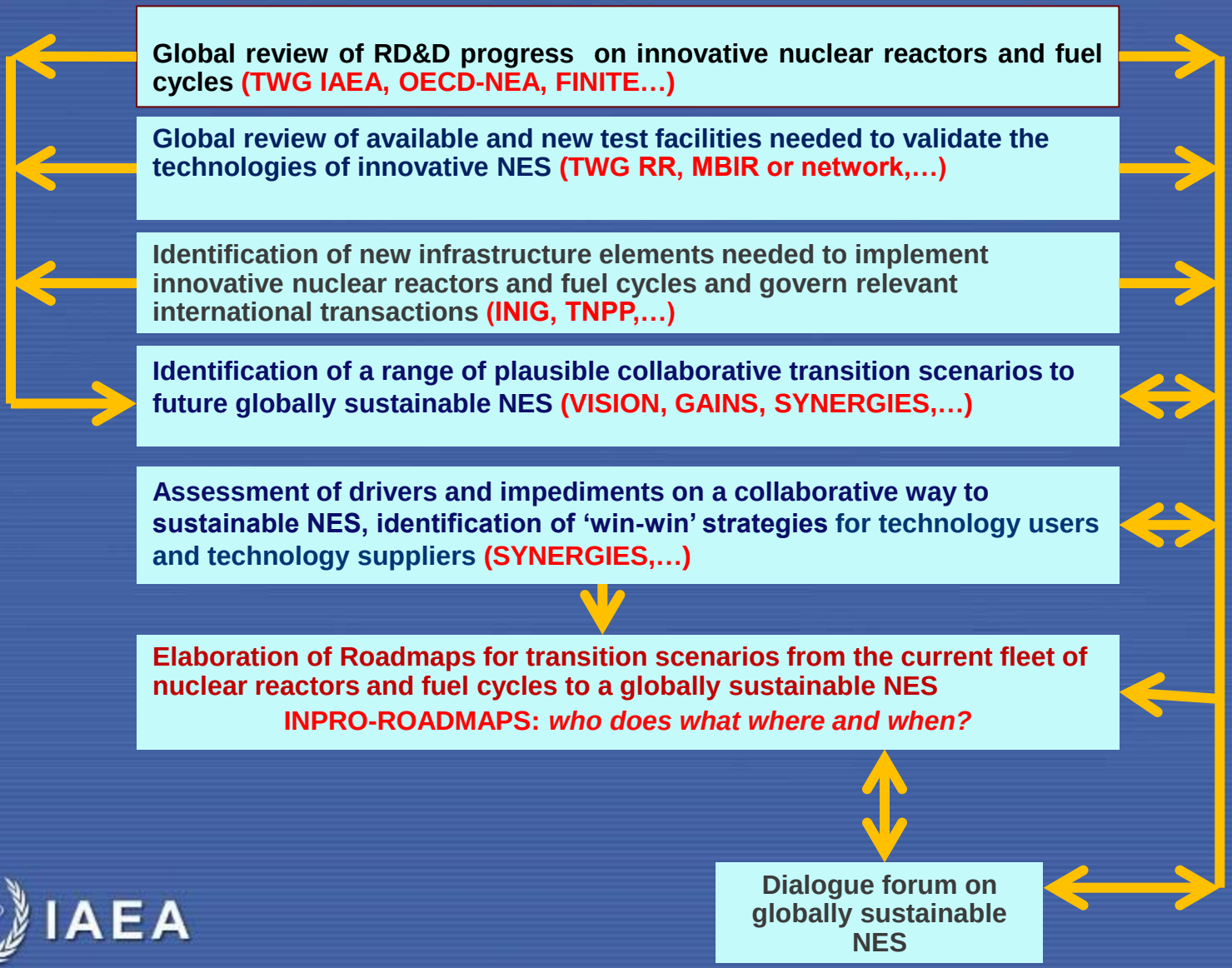
ROADMAPS - Structure



INPRO Dialogue Forum 4, 30 July – 3 August 2012, VIC, Vienna

- Dialogue Forum on Drivers and Impediments for Regional Cooperation on the Way to Sustainable Nuclear Energy Systems
- (INPRO Project 4 ”Policy and Dialogue”)

- Objectives:
- - to bring together technology holders and technology users to exchange views on the benefits and issues associated with regional cooperation in building sustainable nuclear energy systems (NES)
- - specifically, to understand the standpoints of the user and the supplier countries regarding the driving forces and the impediments for such a cooperation

- Participation: 39 participants and presenters from 30 IAEA Member States
- In-house collaboration: TC, NSNI, SG, PESS, NEFW, NPES, INIG
- Funding: TC & US PUI Funds under the Interregional TC Project INT2017-9001-01

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- Summary of identified drivers:
- Option to enhance energy security through assuring energy independence on regional level
- Economic and macro-economic factors: possible benefits measured in cost savings and mitigated investment risks
- Option of shared resource management (collaboration in R&D, shared R&D infrastructure, expertise sharing on licensing, regulations, EIA, radiological protection, etc.)
- Security of supply considerations (assurance of supply, effective spent nuclear fuel management)
- Considerations of ultimate waste management (shared repository costs, etc.)
- Option of best practice sharing, including safety
- Considerations of risk management, including several models for shared NPP development with vendor

INPRO Dialogue Forum 4, 30 July – 3 August 2012, VIC, Vienna

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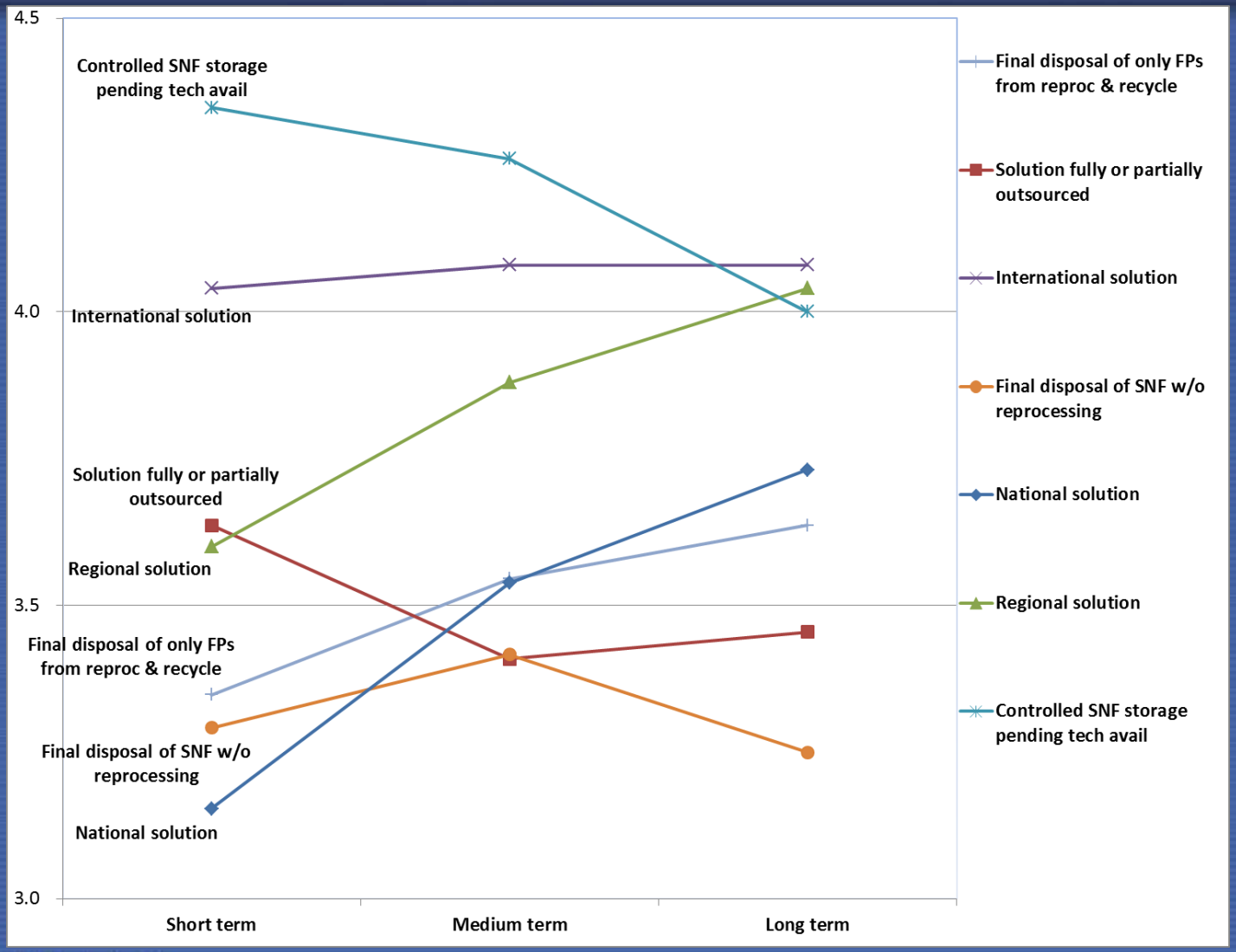
- Summary of identified impediments:
- National regulations which are still essentially a national focus and sometimes prohibit synergistic collaborations with other countries
- National laws that mostly prohibit accepting third parties' ultimate waste for storage and final disposal
- "Wait and hope for Generation IV" considerations which could be expressed as "why invest in new Generation III produces if Generation IV would provide better solutions in a number of years"?
- Considerations of sovereignty
- Protective policy rejecting solutions that are "not invented here"
- Non-uniform socio-political stance on nuclear energy across the region (which might affect deployments in countries where the stance is positive)

Questionnaire Part 3: NG1+NG2+NG3



THANK YOU!

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Back-up slides

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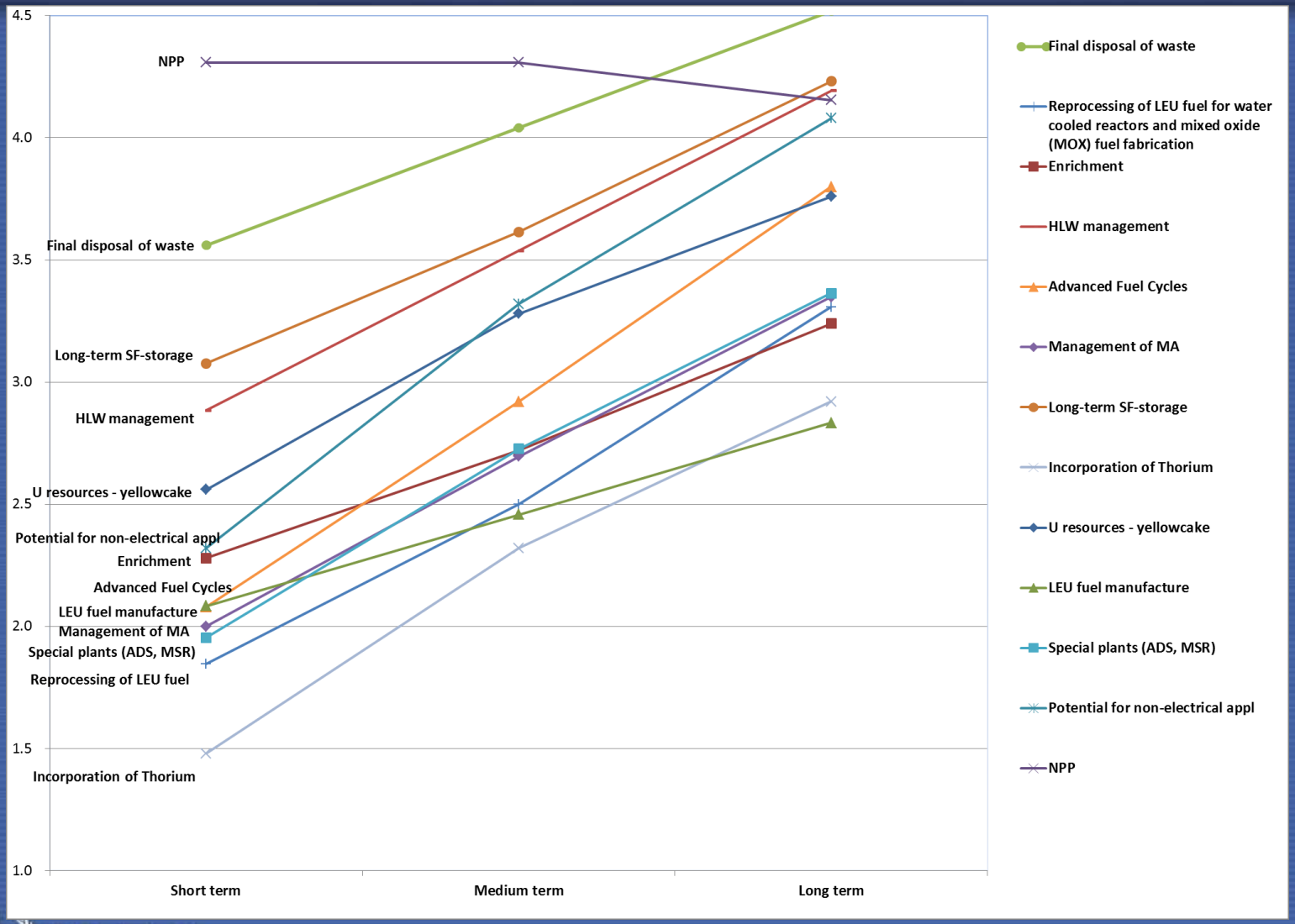
Part 1: NG1+NG2+NG3



INPRO DF 4: Questionnaire

- Section 1. Please, prioritize the importance of collaboration with other countries on particular issues in each of the empty boxes below using a 1 to 5 scale (1 – low priority, 5 – highest priority).
- Section 2. With respect to a nuclear energy project in your country, please, indicate your vision of the importance of economic indicators in each of the empty boxes below using a 1 through 5 scale (1 – lowest importance, 5 – highest importance).
- Section 3. With respect to your country, please, indicate your preferences regarding the approach to final disposal of radioactive waste in each of the empty boxes below using a 1 to 5 scale (5 – most preferred, 1 – least preferred).
- Section 4. Please, indicate which stages of the front-end nuclear fuel cycle your country has mastered (or considers to master) indigenously
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- Section 5. Please, indicate which of the issues mentioned below are (or may become) important with respect to a nuclear energy project in your country. Please, use a 1 to 5 scale (1 – not important, 5 – very important)
- Section 6. Please, answer the following questions

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Targeted nuclear energy system ← Current nuclear energy system

INPRO PROJECT 1

Nuclear energy system assessment for sustainability (using INPRO Methodology for nuclear energy system assessment)

Modification of targeted nuclear energy system based on the outputs of the assessment

Desired degree of innovation in technology and infrastructure

INPRO PROJECT 3

Collaborative projects on selected topics of innovative nuclear technology and infrastructure

INPRO PROJECT 2

Global and regional *scenarios* of transition to future sustainable nuclear energy systems *(resources, spent nuclear fuel, economics, PR)*

Role of cooperation among countries in making such a transition

Synergies and 'win-win' strategies of collaboration between suppliers and users

Roadmaps for transition to future sustainable nuclear energy systems *(who does what, where and when?)*

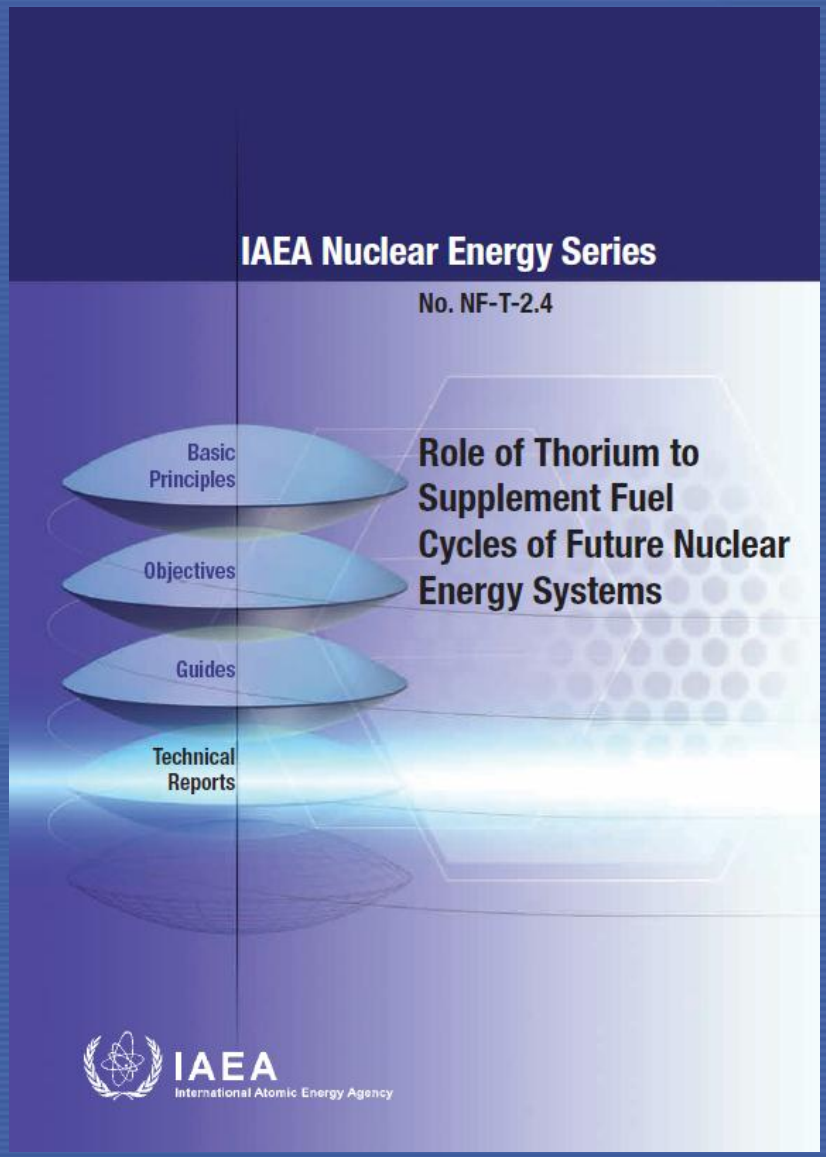
Long-term national nuclear energy strategy/ policy for cooperation with other countries

Project 2: GLOBAL NUCLEAR ENERGY SCENARIOS

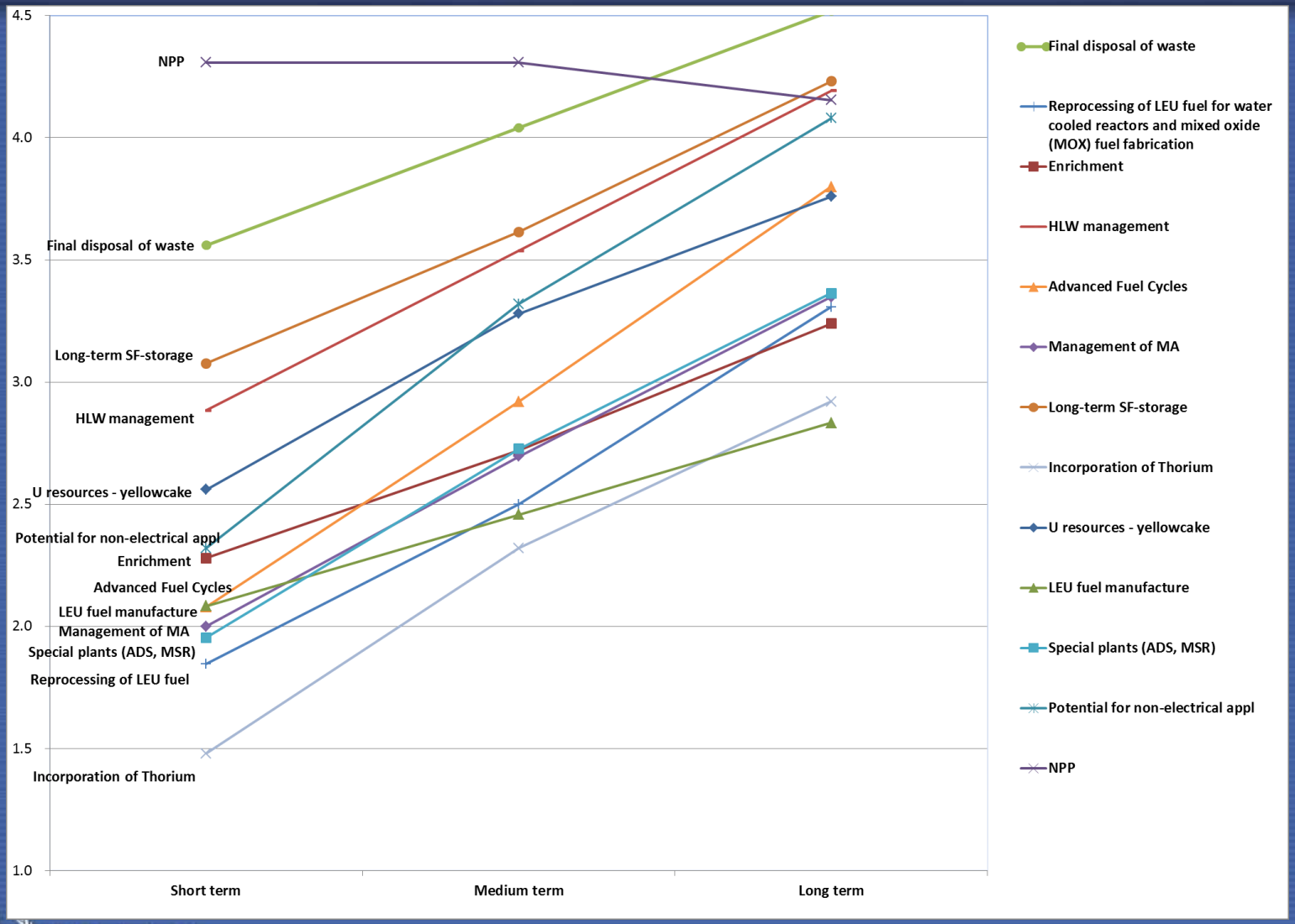
- Collaborative project ThFC (2009-2010)
- Nuclear Energy Series No. NF-T-2.4 published in 2012:

http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1540_web.pdf

- - considered the potential role of thorium to supplement the uranium–plutonium fuel cycle in scenarios with a significant increase in the use of nuclear energy in the world



Part 1: NG1+NG2+NG3



Areas for additional key indicators could possibly be considered

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- Improvement in macro-economic indicators as an expected result of increased installed capacity (KI-1, EP-1.1) - Expected increase in Per-Capita Electricity Consumption, leading to increase in:
  - ✓ Human Development Index
  - ✓ Gross Development Product
  - ✓ Life Expectancy at Birth
- Benefit for technology/industry development
- Benefit for human resource development
- Level of related infrastructure development/ Benefit for national infrastructure
- Sustainable solution for waste (KI-5, EP-5.1, EP-5.2)

Areas for additional key indicators could possibly be considered

- Minimizing electricity generation cost (KI-9)
- Benefit for science and technology development
- Energy security
- Energy independence
- Pollution reduction
- Allow for economy of scale
- Accelerate project implementation (EP-1.1)
- Enhance negotiation position with technology vendors (Security of supply)
- Nuclear PoliCY stability (DELAYS AND IMPACTS)
- Minimize use of primary resources (KI-2, EP-2.1)

Areas for additional key indicators could possibly be considered

- Increased quality and security of energy supply
- Investment costs (EP-9.1, KI-10)
- Technology transfer

Maybe we need a Master Plan to introduce nuclear technology for power generation in the long term

INPRO ROADMAPS activity is expected to produce such a Master Plan