Quantification of Effects of Multi-lateral Cooperation in INPRO Scenario Studies on Nuclear Power Deployment

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Global sustainability as an objective and background for multi-lateral nuclear approach (MNA)

General background for MNA

- Sustainable development is an established UN target but it can not be reached locally, in one country or region
- The mode of NP development within national borders/resources becomes a brake in the world coming to enhanced cooperation & confidence
- Different countries have different abilities and views on the arrangement of the national NP providing a basis for complementarity & harmonization

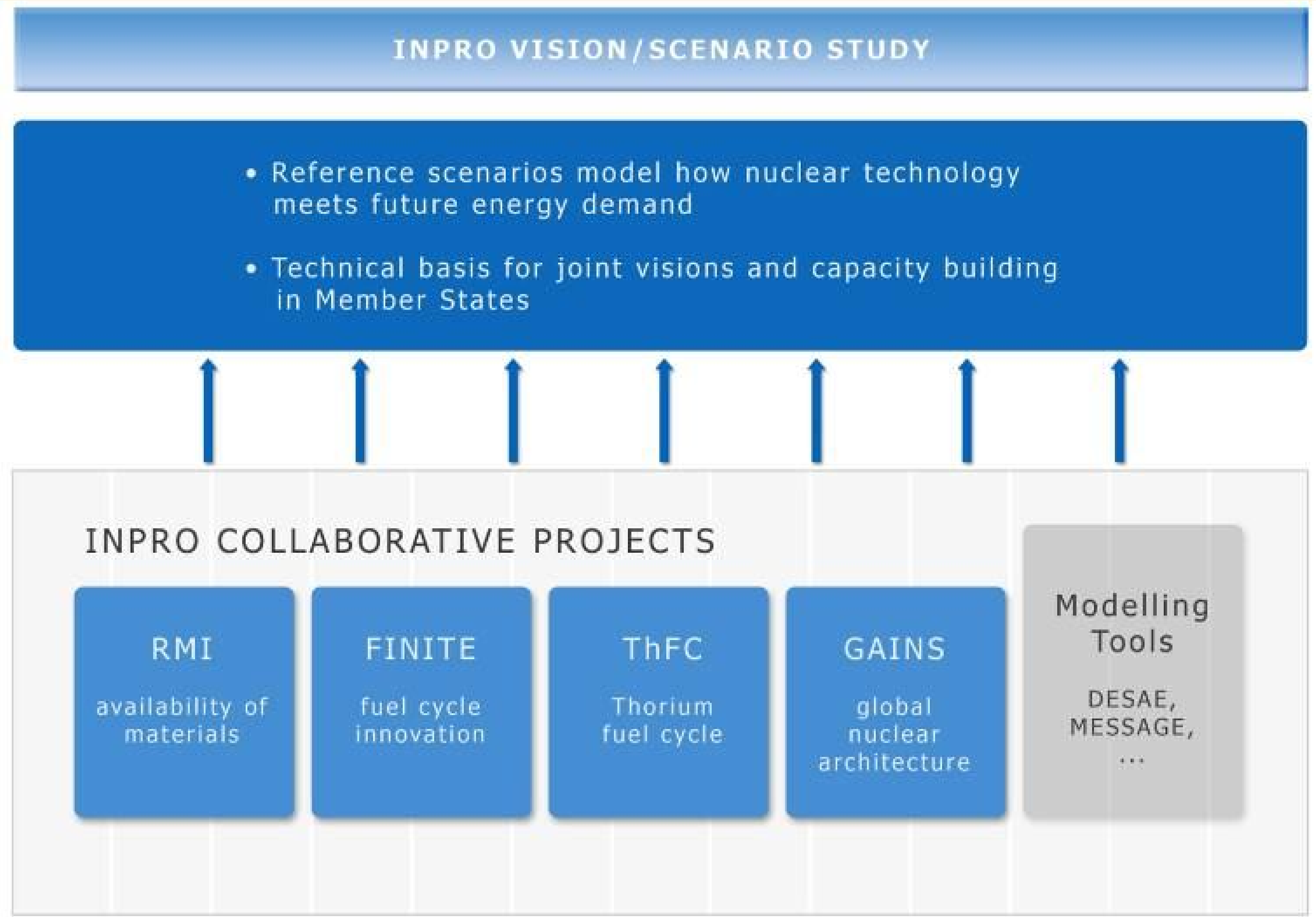
The overall objectives of the activities in INPRO Programme area B (Global Vision, Scenarios & Pathways to Sustainable Nuclear Development)

- Understand the potential of technical innovations and **new institutional approaches** for developing and building a sustainable nuclear 'architecture' in the 21st century
- Develop a framework (a common methodological platform, assumptions & boundary conditions) and case studies for analysing of transition **scenarios from present to a future NP** aiming to facilitate its increased use while minimizing financial, environmental, and political risks

Activities & approaches in programme area B related to modelling of multi-lateral arrangements

- **Activities**
  - Studies
  - Collaborative Projects
  - Codes cross-checking, harmonization, and development
- **Approaches**
  - Development of ***long-term scenarios*** *basing on 'what if approach'* and not aiming for *predictions*
  - Examination of the evolution of ***global nuclear fleet, and fuel cycles*** at different points of time, in different regions and groups of countries
  - Consideration of ***different aspects of sustainability*** effected by MNA (economics, waste, proliferation resistance, infrastructure & institutional arrangements, etc.)
  - Using ***different modeling approaches***, in different depth
- **Good established cooperation with IAEA programmes (PESS, NEFW, NS)**
- **Estimation of synergistic effects of regional and global cooperation is an important part of activities within INPRO Programme area B**

Organization of activities on Global Vision, Scenarios & Pathways to Sustainable Development (INPRO Programme area B)



INPRO study (2009): “Global Scenarios and Regional Trends of Nuclear Energy Development in 21-st Century”

- ***The study*** was launched in January 2009 and concluded with a final draft report at the end of the year (report is expected to be published this year)
- ***Experts*** from China, the Czech Republic, India, Italy, the Russian Federation, Slovakia, and the European Commission collaborated with five MSs that participated as observers: Canada, France, Japan, Ukraine, and USA

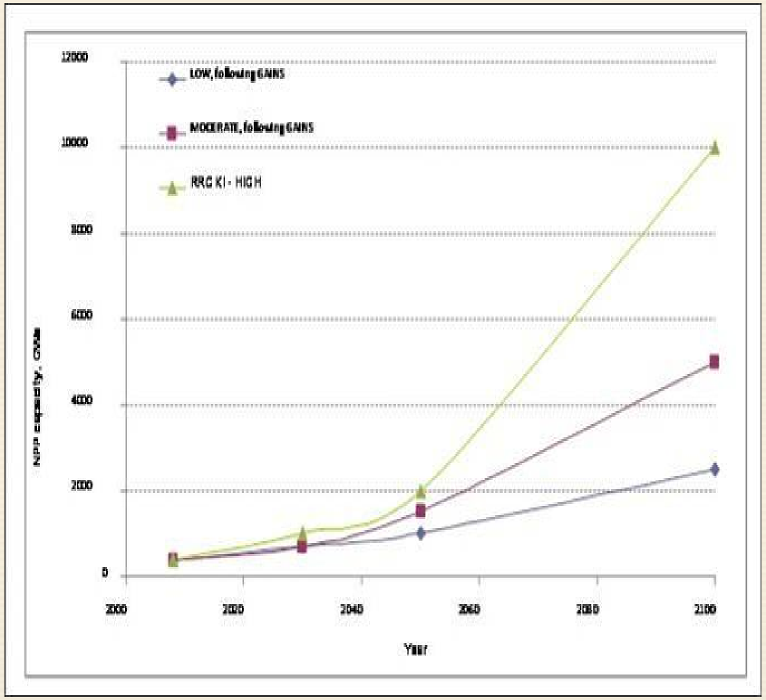
Main assumptions:

- Modelling on basis of world ***regions***
- ***Multi-criteria assessment*** in seven INPRO methodology *areas* — economics, infrastructure, safety, waste management, proliferation resistance, physical protection, and environment
- ***Nuclear global demand*** was agreed for low and medium scenarios with CP GAINS which started 2008 but more ambitious NP growth (high) was added for investigation
- ***Uranium resources*** were limited to ***20 million tons*** within the century
- The analysis deals with ***nuclear energy only***

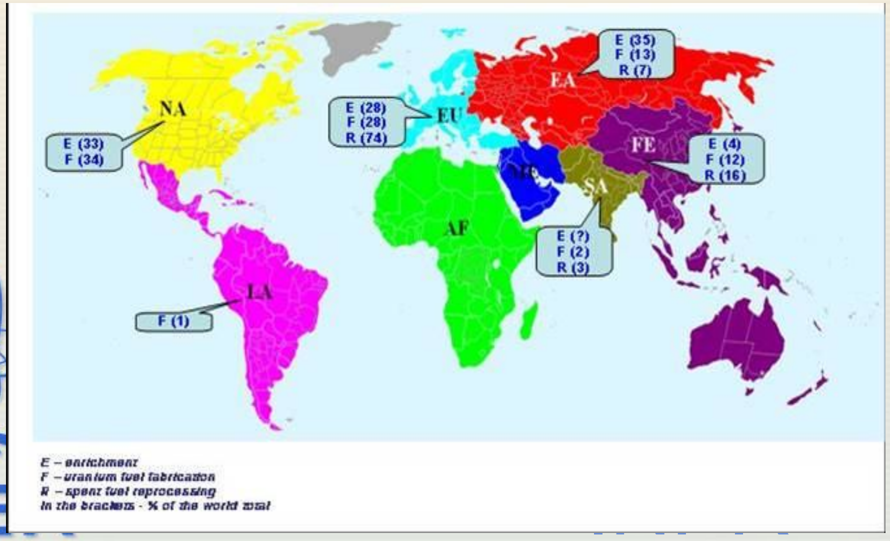
Results of the study should not be considered as a forecast of regional nuclear power development, or global projection

Modelling Approach: Regional

Three scenarios Year/GWe installed	Low (GAINS moderate) GWe	Moder. (GAINS high) GWe	High GWe
2030	500	600	700
2050	1000	1500	2000
2100	**2500**	**5000**	**10000**



Eight geographical regions	
North America (NA) **Latin America (LA)** **Europe (EU)** **Eurasia (EA)**	**Africa (AF)** **Middle East (ME)** **South Asia (SA)** **Far East and the Pacific (FE)**



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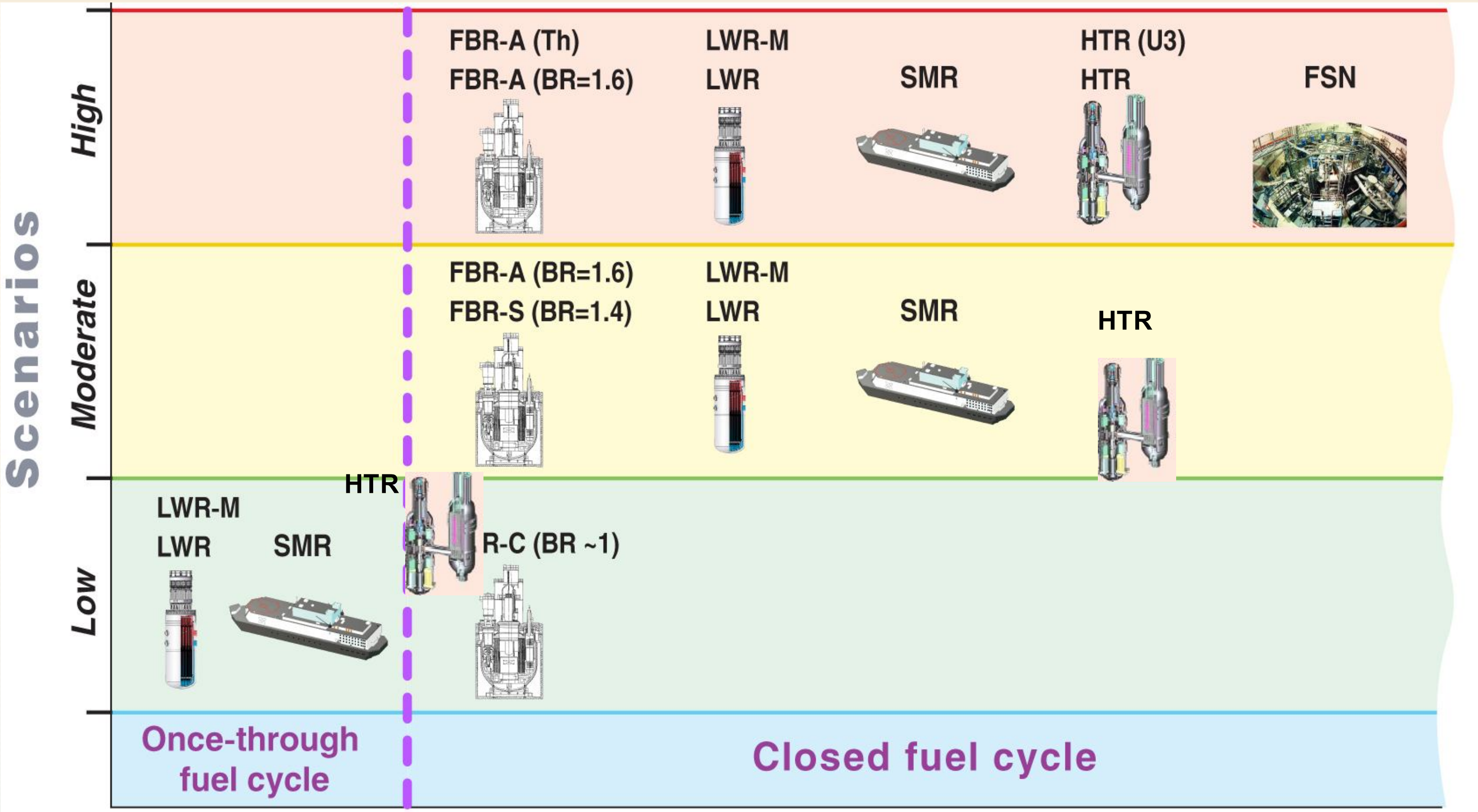
World nuclear energy systems under different development scenarios



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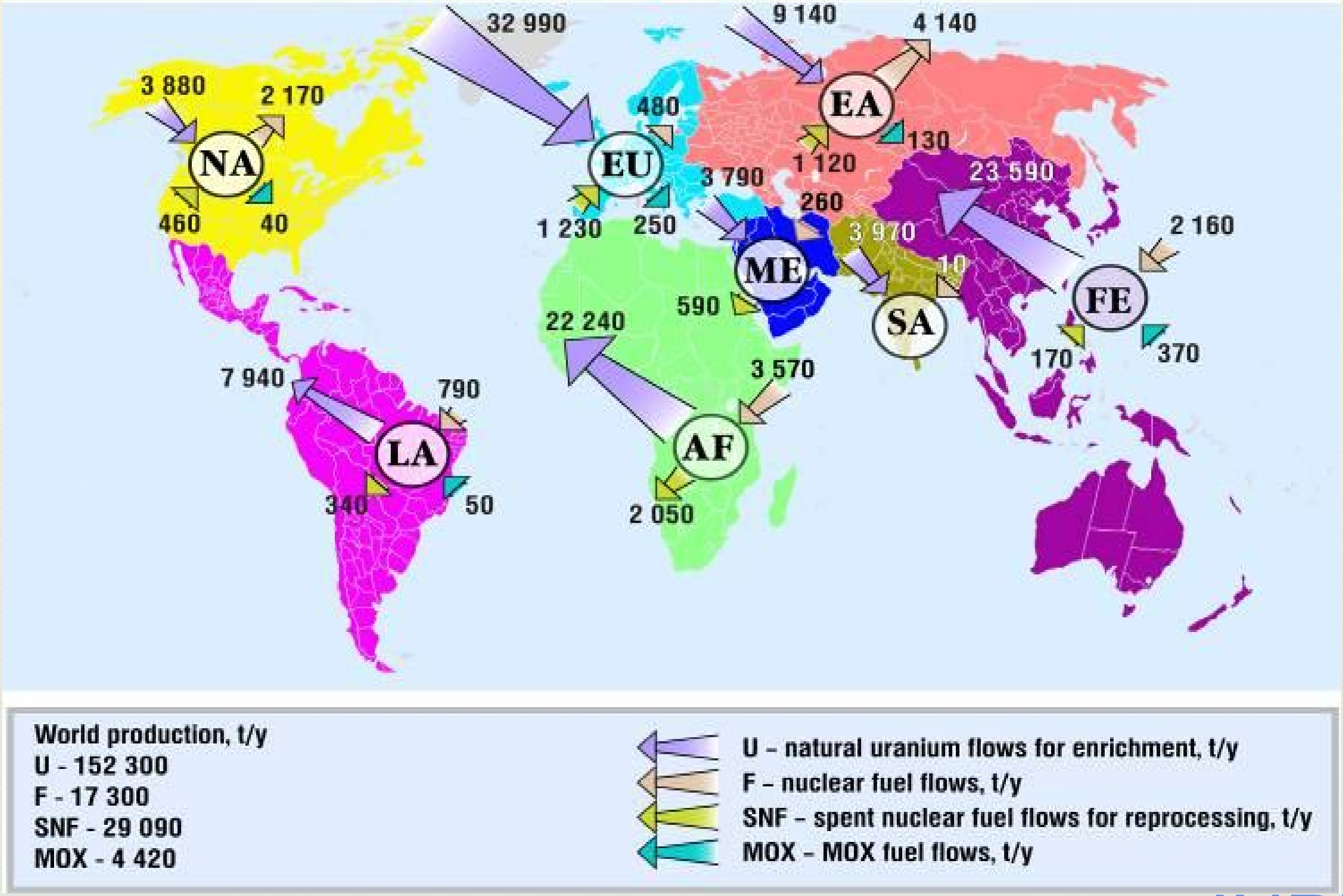
Calculations / Example

- Interregional flows of uranium, fresh, spent and MOX fuel under ‘high’ scenario (2050)



Some findings of the study related to MNA

- Within 20 mln. t U, the 'low' scenario based on thermal reactors (TR) is shown to be feasible. But it poses ***complex problems of SF storage, disposal, property & liability***
- International cooperation in ***establishing regional fuel cycle centres*** and associated waste disposal facilities might alleviate this concern
- Introduction of FBRs with a breeding ~ 1 from 2030 reduces U demand by a factor of 2 and lead to a ***substantial decrease of SF for final disposal***
- In the 'moderate' scenario, U limitations require closing of the NFC and essential introduction of FBR in combination with TRs. Delays in closure of NFC would require over-proportional ***increase of U production, enrichment and storage capacities***
- The model requires ***wide distribution of FBR, enrichment and reprocessing facilities*** in all regions posing many ***challenges related to non-proliferation, transport, fuel supply, etc.***
- Non-technical challenges could present ***a serious barrier to the rapid growth of NP and would require appropriate international efforts***

Further steps on quntification of MNA effects is being done in CP GAINS

Collaborative project GAINS

- ***Under implementation*** since 2008
- ***14 countries and EC***
- Based on ***activities of participating MS***
- Results received are being analyzed and summed by ***nominated experts*** at the ***regular consultacy meetings*** of the project (twice a year)

Main assumptions:

- Modelling is based on a technological ***multi-group approach***
- ***Multi-criteria*** assessment
- ***Uranium resources*** are assumed to be not limited but assigned to different cost groups

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MS - PARTICIPANTS of GAINS

Belgium, Canada, China, Czech Republic, France, India, Italy, Japan, Republic of Korea, Russian Federation, Slovakia, Spain, Ukraine, USA, EC and Argentina as an observer

Heterogeneous model of a global NP: a new tool in scenario studies

Homogeneous model is usually used in scenario studies

The model assumes simultaneous introduction of innovative NES all over the world thus giving idealistic, sometimes misleading picture of the nuclear future

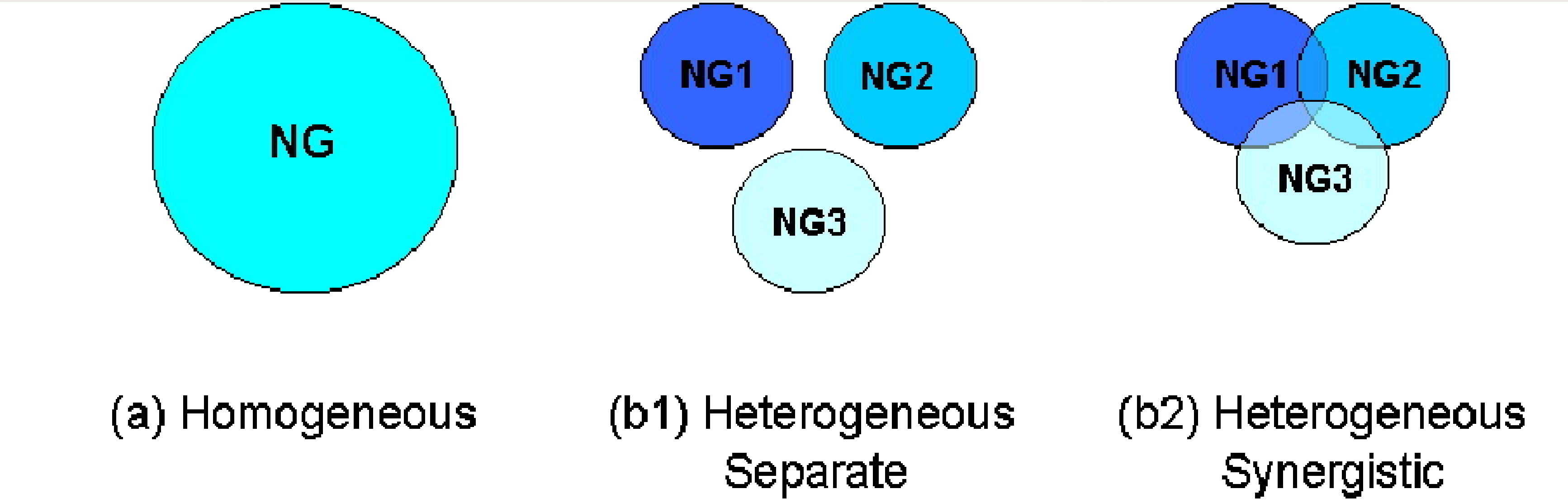
One of the GAINS focuses is to develop, jointly with IAEA experts, a **heterogeneous model**, more realistic than homogeneous one

- GAINS emphasizes not geographic but technological aspect of NP deelopment
- In a het. model, NFC in different groups of countries is different
- Differences create incentives for mutually beneficial collaboration
- The nuclear energy producing groups are defined as follows:
  - **NG1:** adanced NFC, including recycling of used fuel;
  - **NG2:** either directly disposing of used fuel, or reprocessing used fuel abroad
  - **NG3:** using fresh fuel, and sending used fuel abroad for either recycling or disposal, or back-end strategy is undecided

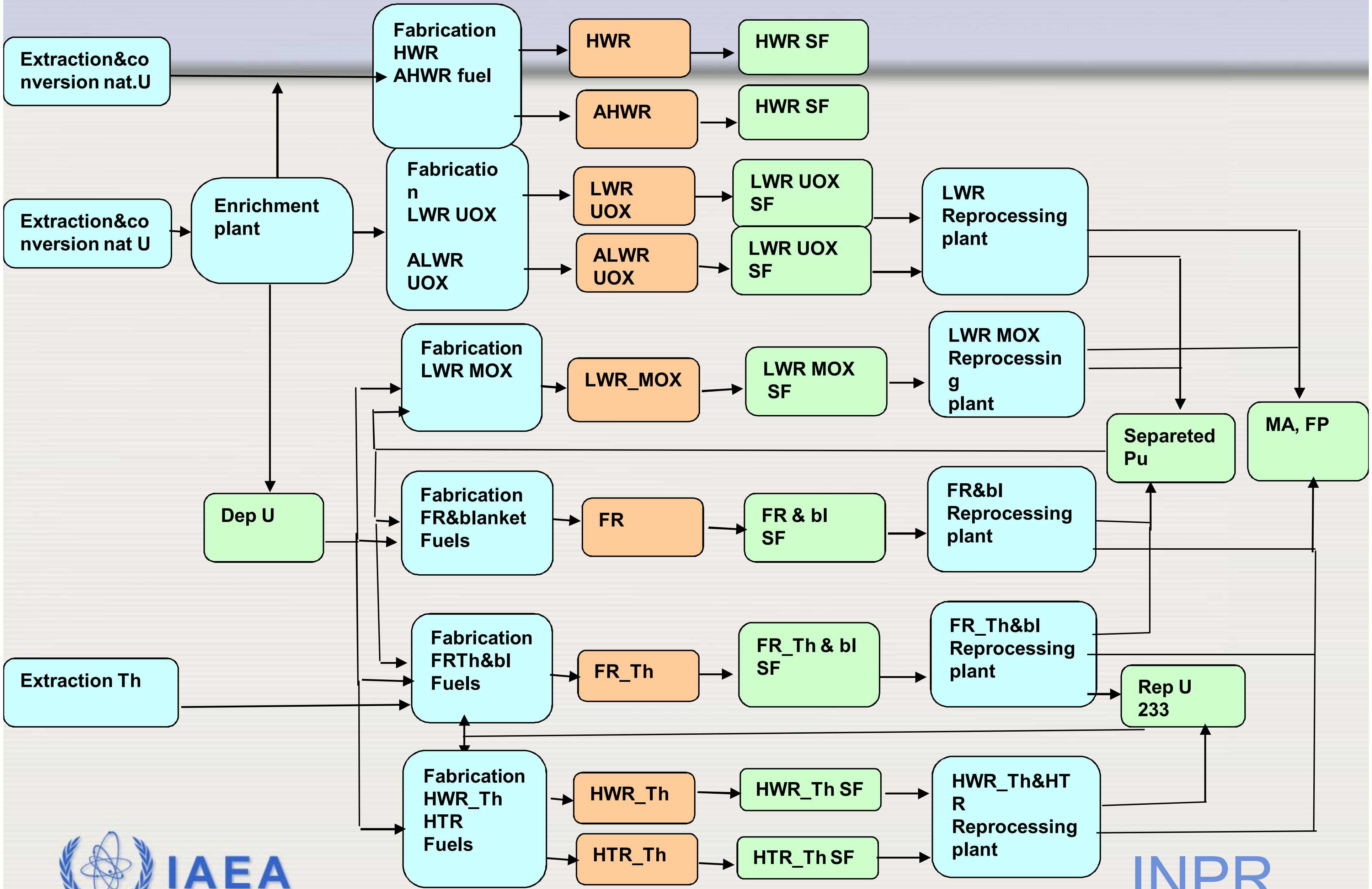
Important issues

- What MS have a technological & financial potential to recycle and/or build geological repositories in a long-term perspective? Which of them intend to realize it?
- Could technological progress in one group really influence security, sustainability & cost of a global NES?
- Why and when to make steps for introduction of FR and/or closed FC?
- How strategies could look with and without multilateral global architecture?
- What type of reactor and NPP select for different groups? How and when intergroup nuclear services could be provided?

What synergetic architecture (MNA) can provide?



Introduction of NFC in NG1



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Tools for simulation of scenarios

- **IAEA's codes:**

  MESSAGE (IAEA/PESS),
  NFCSS, former VISTA (IAEA/NFCMS),
  DESAE (IAEA/INPRO)

- **National computer codes:**

  COSI (France)
  TEPS (India)
  FAMILY (Japan)
  DESAE, etc. (Russia)
  DANESS, VISION (USA)

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Indicators for the NES sustainability analysis

- **Economics** → NS energy production, system investments, total INS cost, energy generation cost
- **Environ-ment** → U/Th consumption, U&TRU isotopes inventory, radionuclide emissions
- **Waste** → Mass and activity of SF, isotopes inventory, incl. FP & MA, heat release, radiotoxicity
- **Prolifer. resistance** → Fissile materials inventory and balance, SWU, heat release
- **Infra-structure** → Capac. of fabr.& rep. plants, NPPs, storages, repositories, optimal INS introduction

All indicators provided by tools are useful; several new ones have to be introduced

Global challenges in NE development addressed in the study

Assurance of fuel supply

- Uncertainties in evaluation of the amount of cheap uranium resource and the unevenness of the U deposits distribution

Nuclear waste

- Continuing accumulation of SF and HLW

Assurance of non-proliferation

- Concern of the fissile material use in non-civil applications

Economics & finance

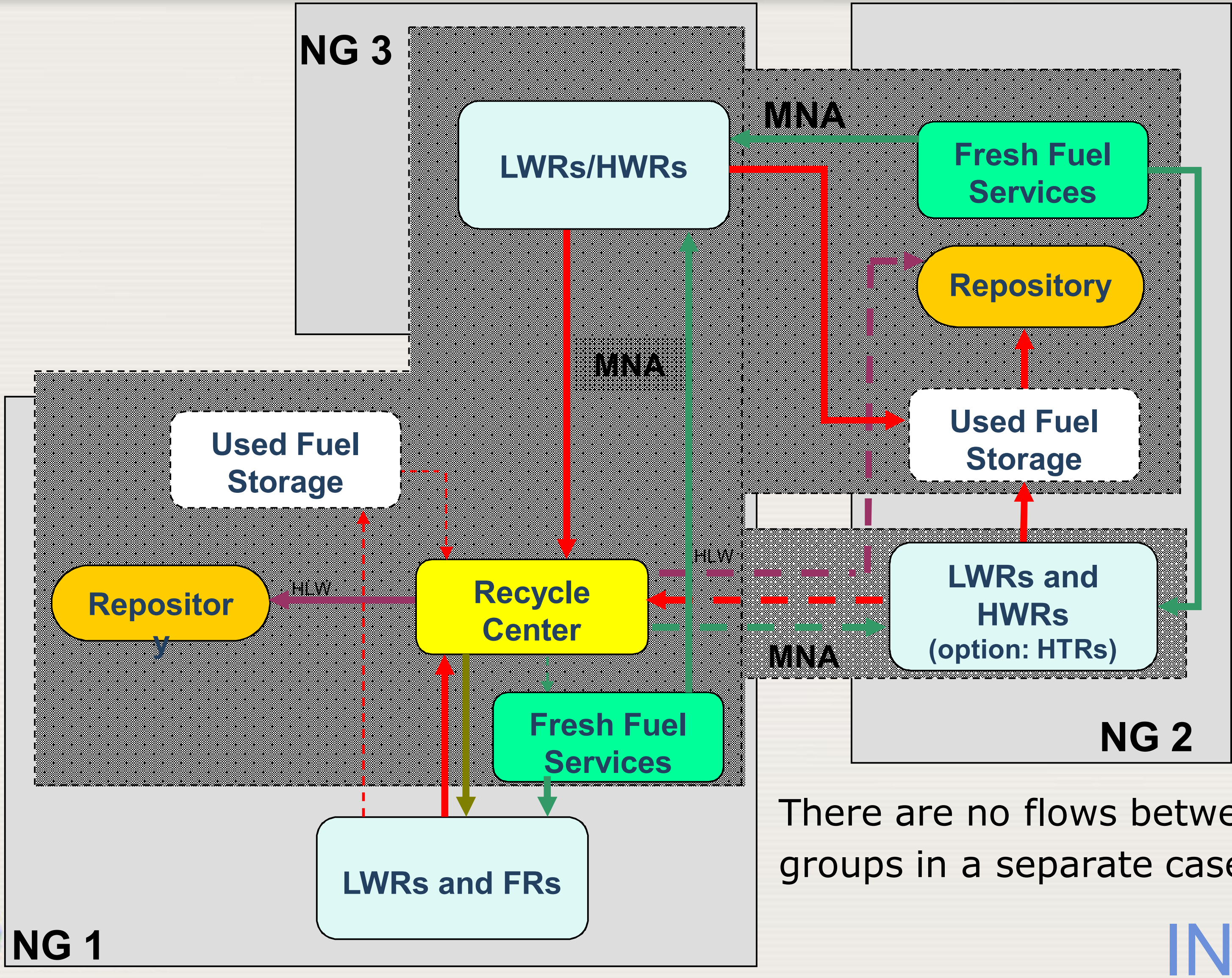
- Need for huge investments in RD&D and NES deployment

Technology, industrial & institutional infrastructure

- Sophisticated technology sensitive to public opinion, requiring high-qualified human resource, significant and long-term liabilities

MNA is to be an integral part of a global response to global challenges

Example: Synergistic Case with Flows Shown



There are no flows between groups in a separate case

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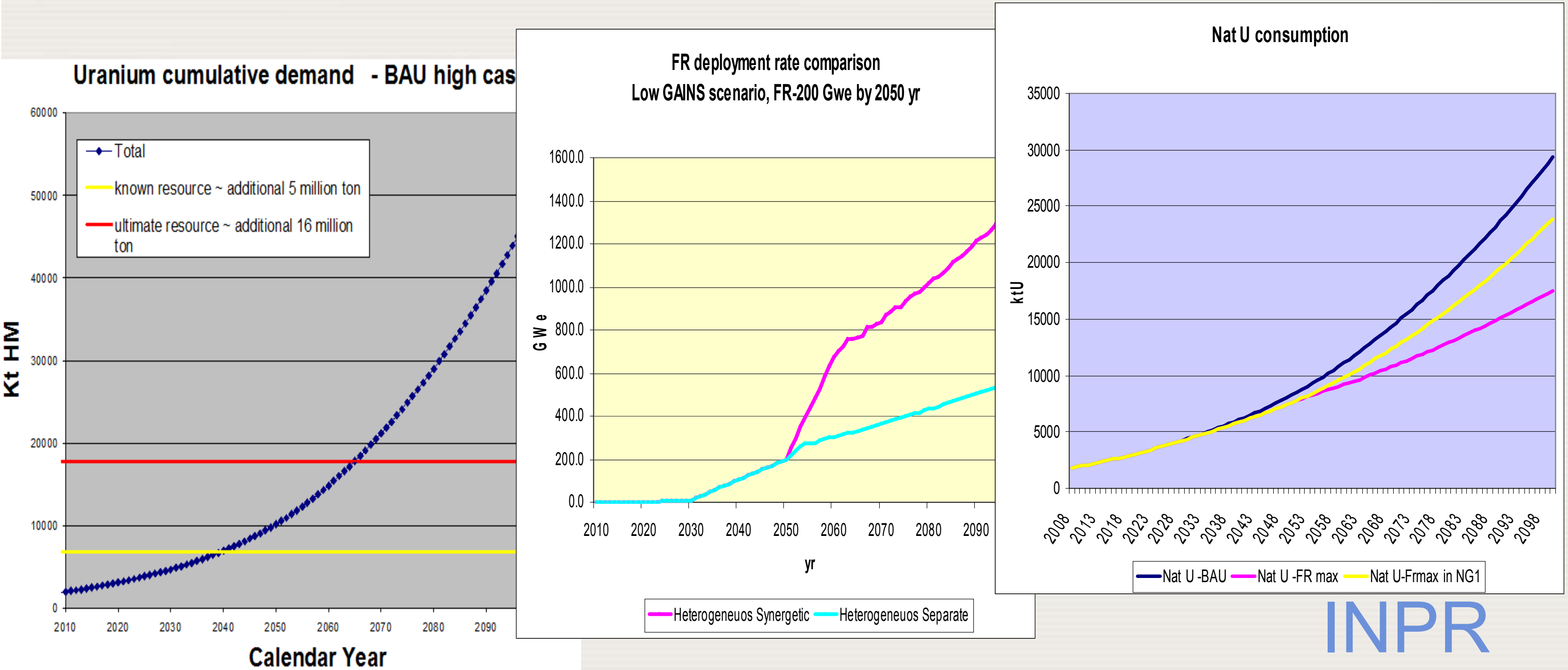
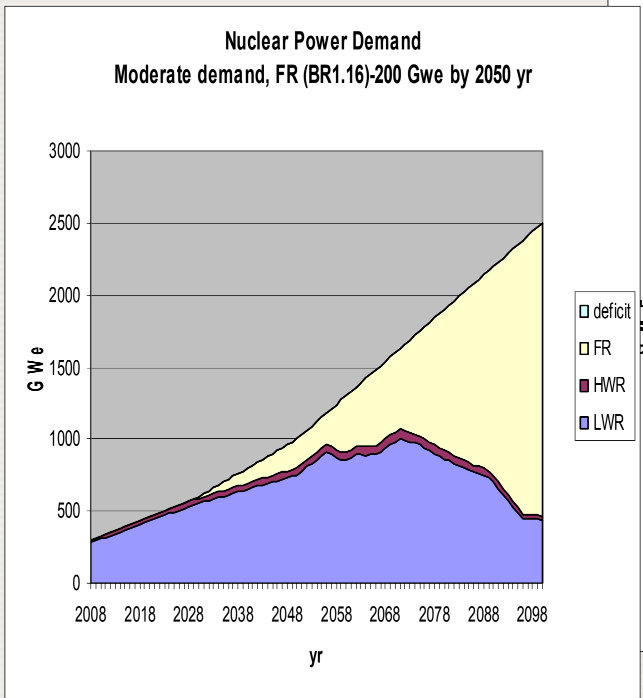
Assurance of fuel supply (1/2)

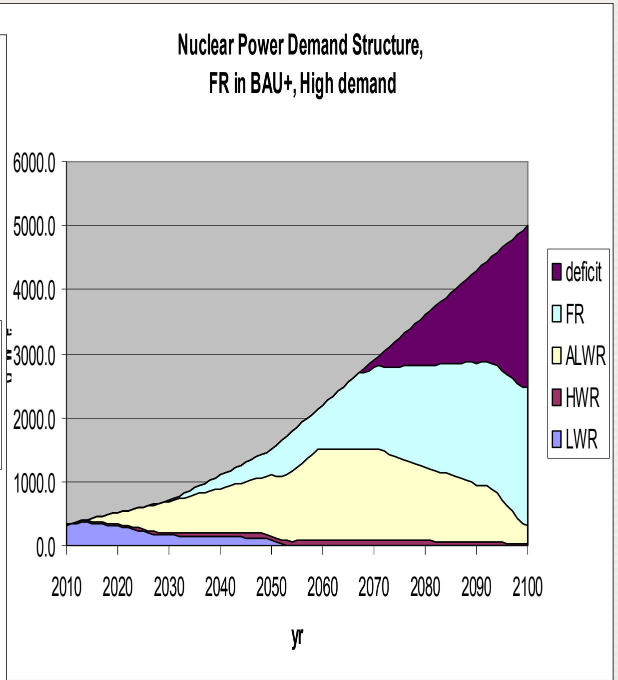
- Cross-checked: **demand of nat. U** for business as usual (BAU) scenario is **higher of prognosticated ~16 Mt U** leaving alone **~5 Mt of identified U**
- Introduction of CNFC-FR in one group within separate case model **does not solve the problem of U resource radically** (saving ~20%)
- **MNA** works as an **amplifying factor** assuring MOX fuel for **higher FR growth** (*red line in the middle fig vs green one*) thus **saving 7-10 mln tU,** more than identified U resource



Assurance of fuel supply (2/2)

- Within MNA, prognosticated 16 Mt U **are sufficient to supply** NES TR&FR (BR1.16) that meets **moderate GAINS scenario demand**
- To meet high GAINS demand, U resource 16 Mt **U should be expanded**; or **BR of FR increased**; or **ThFC introduced**
- The **higher scenario** - the **more important the role of MNA**



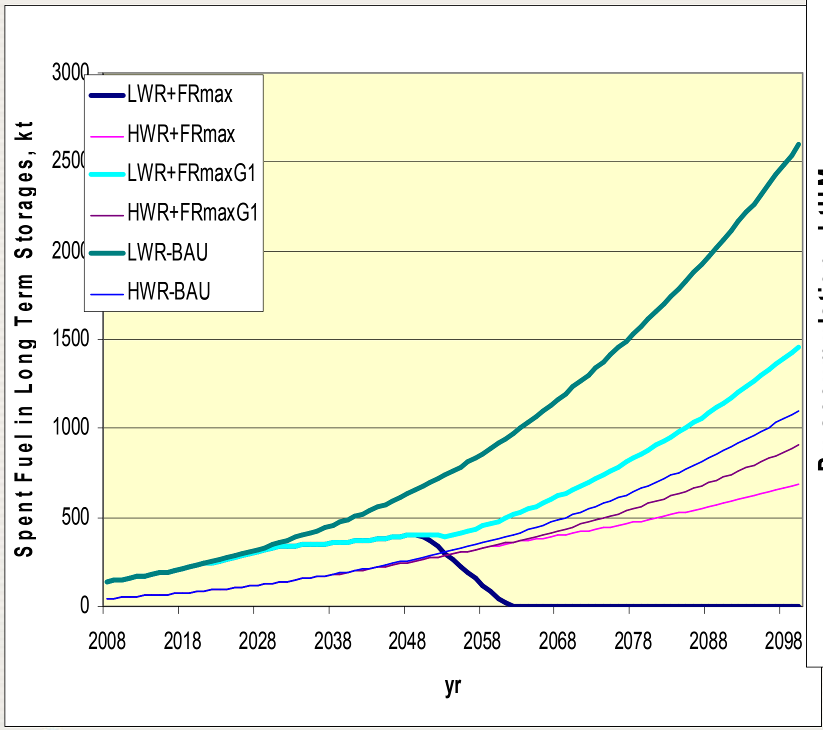


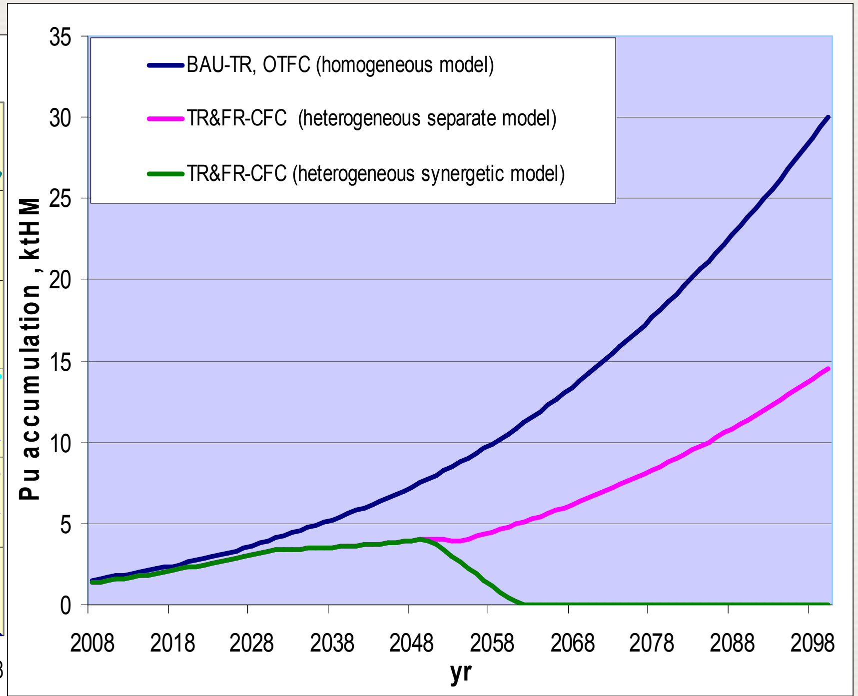
- GAINS admits availability of more than 16 Mt U considering this case in **conjunction with economic and waste management** dimensions

Waste management

▪NES TR&FR (BR1.16)**+**MNA gives an opportunity to **reduce SF & Pu accumulation to a minimal stock** (*deep blue line in the left fig for SF; green in the right fig for Pu*)

▪Ability of 'one stratum' global NES versus 'two stratum' NES with involvement of ADS and MSR for complete **MA (Np, Am, Cm) burning** is under investigation





Assurance of proliferation resistance

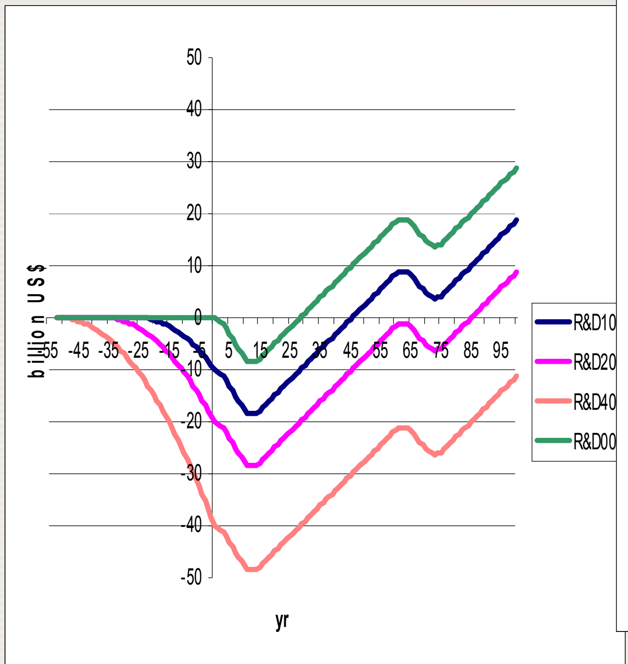
- NES TR&FR+MNA can burn all excessive fissile materials thus giving an opportunity to **balance generation and consumption of FM to necessary level** thus **reducing potential PR risk**. **The balance can not be achieved without MNA**

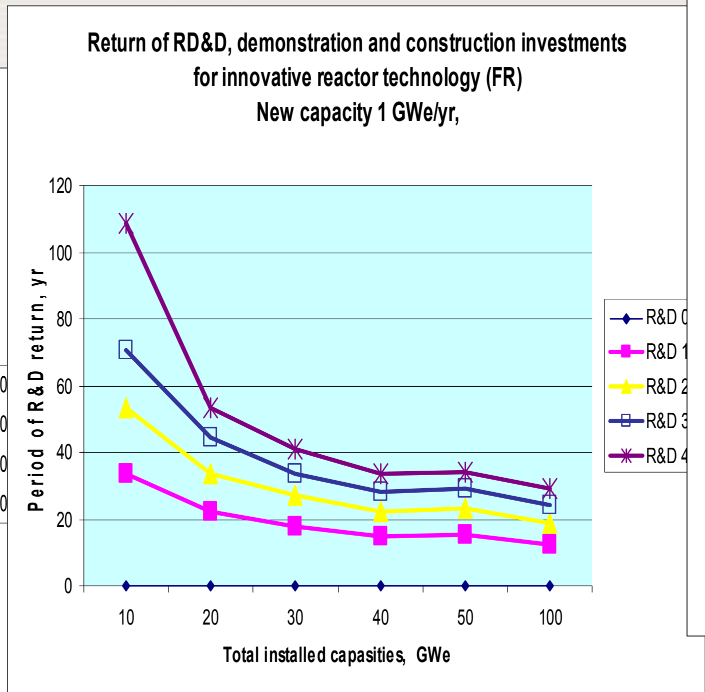
- Preliminary evaluation: a global heterogeneous synergistic model with **MNA can provide saving of SG efforts/costs**

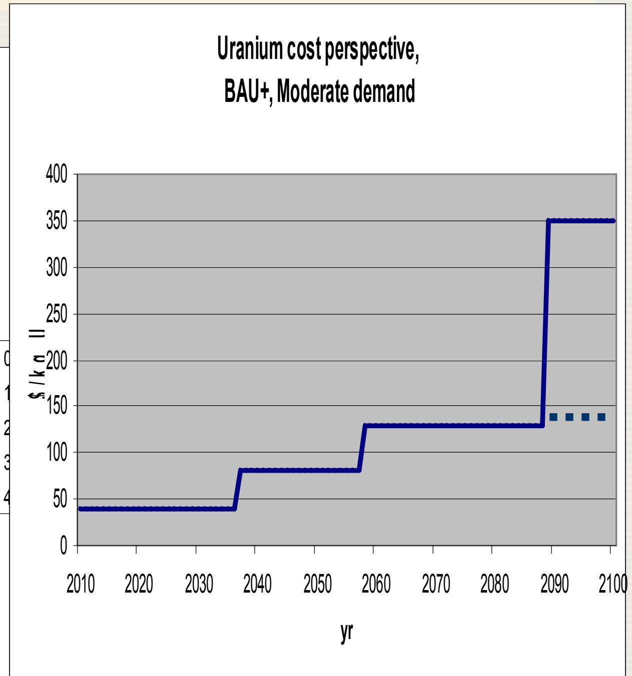
- **PR** is considered in GAINS **for the holistic global NES**. In the spirit of INPRO methodology, **there is no sense to oppose different components of the global NES** (i.e., both enrichment and reprocessing are components of the group 1 infrastructure)

Economics

- **MNA** might help to **reduce risk not to return RD&D & construction investments** in innovations *(the left fig: investment return for innovative NES of 10 GWe under different RD&D cost)*
- **MNA** tends to **postpone the surge of U prices** that is calculated to happen after mid century in a separate configuration of a global NES
- Preliminary assessment has shown that **savings of global investments** under implementation of MNA could be very significant







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Conclusions

- Vision scenario studies within IAEA/INPRO framework is a unique activities capable to provide a ***regular modeling support to practical needs of MS***
- ***Innovative technologies is a driving force*** for enhancing the NP sustainability while ***MNA amplifies positive effect*** of their introduction providing a scale for global response to global challenges
- To improve accuracy of evaluations, ***more detailed architecture of the global NES should be developed in future*** based on the feedback of MS on demand-and-supply potentials, cost of services, desirable links to global infrastructure, etc
- A healthy market based on MNA exists at the front end of NFC. Vision studies identify benefits of MNA at the back end as well, both for technology users & holders. Actualization of this potential substantially depends on political climate and social progress. Development of ***consistent view on MNA*** by nuclear community is also important
- IAEA provides a good opportunity to ***work together towards sustainable nuclear future*** with minimal financial, environmental, and political risks

Thank you for your attention

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