International Symposium on Nuclear Back-end Issues and the Role of Nuclear Transmutation Technology
Kyoto University , 28 November 2013

OECD Nuclear Energy Agency Activities Related to the Nuclear Fuel Cycle

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Outline

- OECD/NEA Membership and Mission
- NFC Scientific Issues
  - Minor actinides management
  - Recycling TRUs
  - Innovative Fuels & Materials
  - Advanced Fuel Cycle Scenarios,
- Workshops, Conferences
- NFC Strategic Issues
  - Trends in the fuel cycle, fuel cycle transition scenarios
  - Economics of the back-end

Mission

- **To assist its member countries in maintaining and further developing, *through international co-operation*, the scientific, technological and legal basis required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes**
- **To provide *authoritative assessments* and to forge *common understanding* on key issues, as support to government decisions on nuclear energy policy and as input to broader OECD policy analyses in areas such as energy and sustainable development**

  - **Forum for sharing national experience**
    - ***Catalyst for developing consensus***
  - **Centre of excellence**
    - ***Network of over 4000 national experts***
    - ***To pool and maintain expertise***
  - **Managerial skills for co-ordinating multi-national R&D projects**
    - ***More than 50 years of experience in managing such projects for the benefit of participating countries***

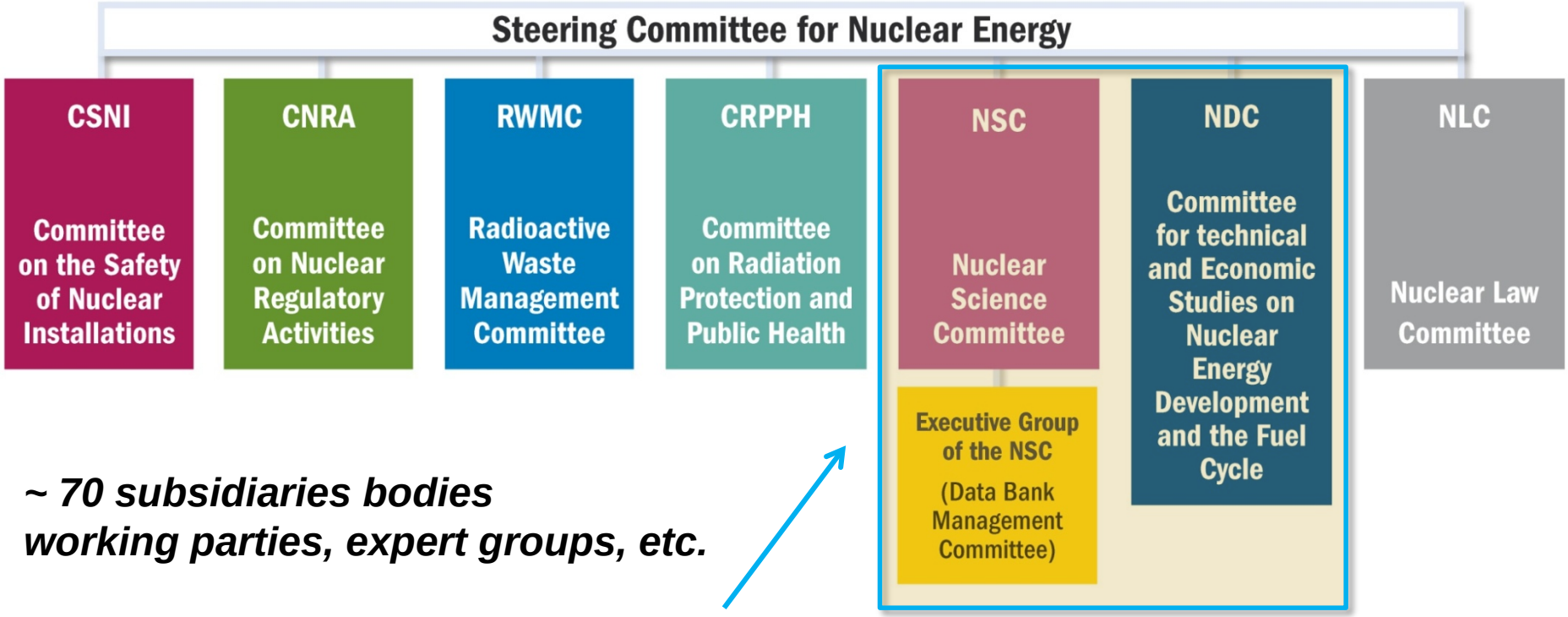
Flexibility

NEA member countries

Russia became most recent member in January 2013

The NEA's current membership consists of 31 countries in Europe, North America and the Asia-Pacific region. Together they account for approximately 90% of the world's installed nuclear capacity.

NEA committee structure



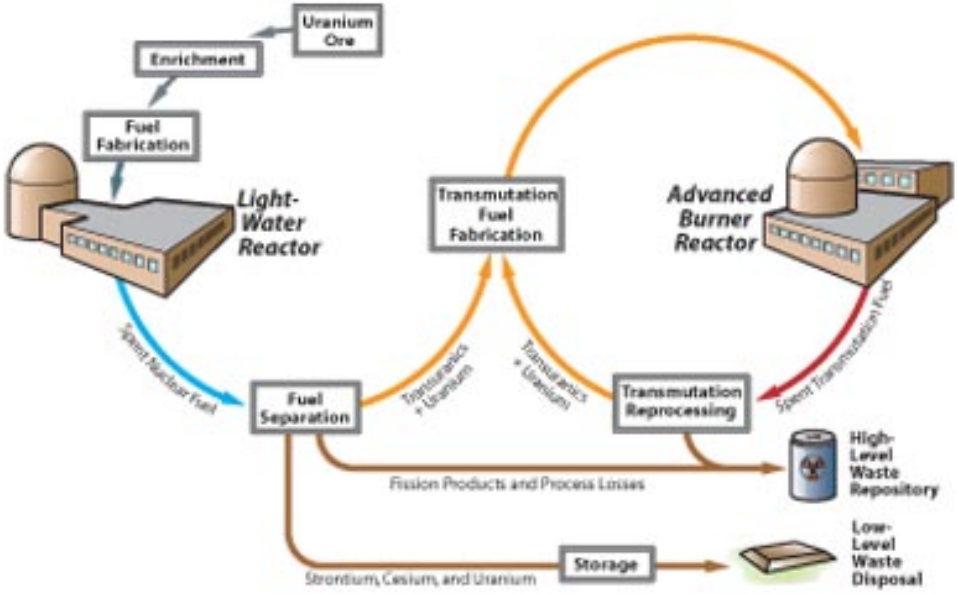
~ 70 subsidiaries bodies working parties, expert groups, etc.

Most of activities described here are carried out by expert groups from these 2 standing committees

NEA also provides Technical Secretariat services to GIF and MDEP

Back-end related activities at OECD/NEA

Advanced Nuclear Fuel Cycle



- Minor Actinide Separation
- Fuel fabrication
- Different options for transmutation: homogeneous, heterogeneous
- Recycling
- Waste management

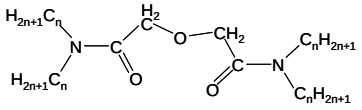
OECD/NEA expert groups are active in all areas of the fuel cycle in particular through the NSC/WPFC

Minor Actinide Separation Technologies

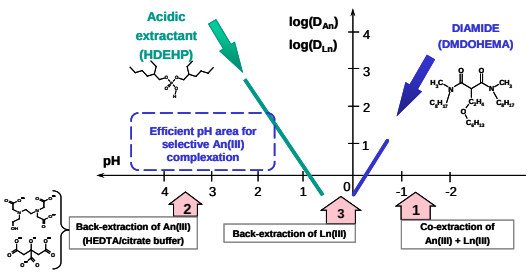
❖ **Report on Progress of Separation Chemistry, Minor Actinide Separation and Perspective of Future R&D**

Hydrometallurgy

- New extractants for selective separation (e.g. diamides)



- Advanced aqueous processes: PUREX, DIAMEX, SANEX, GANEX, EXAm, NEXT, etc



Pyroprocessing

- Electrorefining (chloride molten salts)

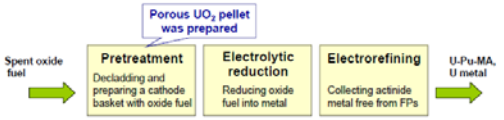
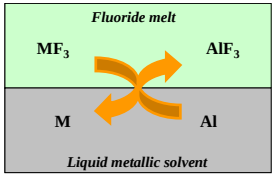


Fig. Pyrochemical reprocessing flow for spent oxide fuels.

- Liquid-Liquid extractions in fluoride media



To be published end of 2014

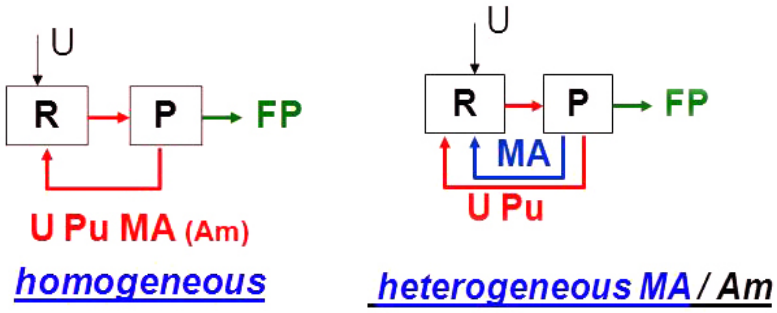
Expert Group on Integral Experiments for Minor Actinide (MA) Management

- **Accuracy of the MA nuclear data needs to be improved for:**
  - **Detailed design of the transmutation systems**
  - **Accurate prediction of the spent fuel composition**
- **Integral experiments for the MAs are scarce due to the restrictions and difficulties in material handling, sample preparation, post-treatment technology, etc**
- **Expert Group launched to:**
  - **Identify requirements of nuclear data for MA management**
  - **Review existing integral data and identifying specification of missing experimental information**
  - **Identify the bottlenecks and considering possible solutions**
  - **Propose action programme for international cooperation**
- **Final report completed**
  - **Np 237, Am 241, 242m & 243, Cm 242, 243, 244 & 245**
- **Follow-up: New Expert Group**
  - **Joint design of reactor physics MA measurements in selected facilities**
  - **International collaboration on irradiation program for MA**

Recycling Transuranics (TRU)

- **State-of-the-art Report on Heterogeneous vs Homogeneous Recycling of Transuranics in Fast Neutron Reactors**

Two mains options are investigated:



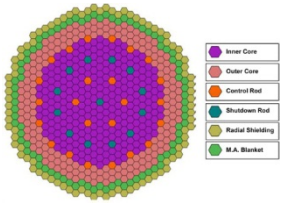
Potential advantages and disadvantages
Issues related to fuel cycle characteristics and fuel forms

- **Comparison of criteria between both recycling modes**
- **Specific implementation scenarios**
- **Non proliferation issues**
- **Strategies for curium management**
- **Specifics scenarios were studied to underline specific needs and requirements**

June 2013

Recycling Transuranics (TRU)

Comparisons of Nuclear Fuel Cycle Issues



Homogeneous mode

- Fuel fabrication easier but impacts all fuel fabrication streams
- Fuel behaviour under irradiation is close to standard fuel
- No flexibility between production of electricity and long-lived wastes mission
- Impacts on core reactivity coefficients limit content of MA

Heterogeneous mode

- Fuel fabrication is more complex
- Fuel behaviour under irradiation is different to standard fuel due to large production of curium and helium released
- No impact on standard fuel cycle
- No impact on main reactor core parameters but higher thermal load
- MA contents are higher

WPFC Expert Group on Innovative Fuels (IF)

Innovative fuels ⟹ heterogeneous & homogeneous fuels, ADS fuels, oxides, metals, nitrides, carbides

Objectives and activities

- ✓ **Support the development of innovative fuels and cladding that can be implemented in advanced nuclear fuel cycles**
  - **Innovative fuel fabrication techniques;**
  - **Irradiation performance of innovative fuels (including advanced clad materials);**
  - **Characterisation and post-irradiation examination methods;**
  - **Predictive models/codes for the innovative fuel fabrication and performance;**
  - **Phenomenological experiments in support of model development or validation**

➢ **Benchmark Study on Fuel Performance Codes**
- ✓ **focus on experiments on MA bearing fuels with different chemical forms.**
- ✓ **results will be gathered into a database**

Minor Actinides Bearing Fuels

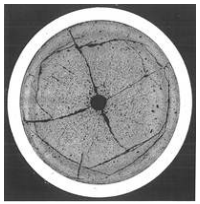
❖ State-of-the-art report on Innovative Fuels

Different types of fuels (heterogeneous & homogeneous)

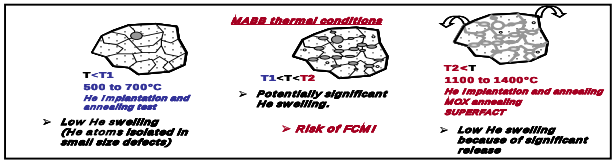
- Metal
- Oxide
- Nitride
- Dispersion Fuels
- Special mechanical forms (sphere pac, …)

To be published in 2014

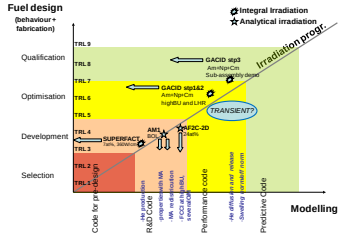
Fabrication & characterisation



Irradiation performance



Safety behaviour



Technology Readiness Level

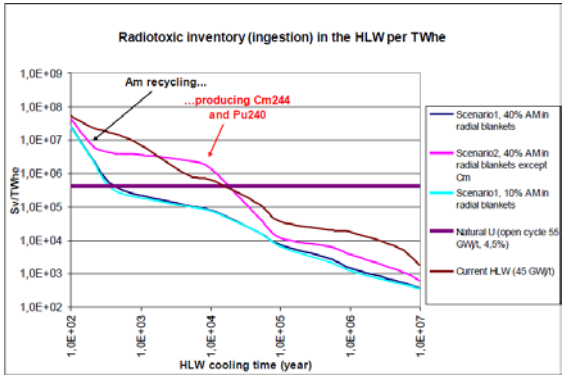
Conclusions:

TRU bearing fuels are being developed at lab. scale and irradiation tests have been limited to small samples. Most advanced are metal and oxide fuels.

Curium management in France, Japan and USA

Management of Cm is challenging, it requires special shielding and handling; reprocessing for separation of Cm and Am

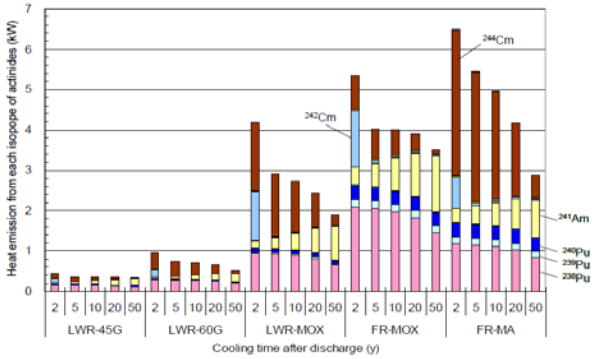
France



- Recycling of all MAs : efficient decreases in radiotoxic inventory and decay heat in HLW
- Removal and decay storage of Cm: overall reduction and minimise shielding and handling requirements

⇨ **Separation studies directed towards separation of Am from Cm and FP in single process (ExAm)**

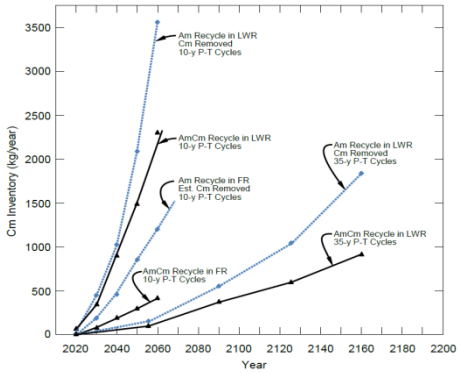
Japan



Main contributors of heat emission are ^{244}Cm, ^{241}Am, ^{238}Pu

⇨ **Cm separation from Am by extraction chromatography**

USA



Cm inventory is greater when Cm is removed and stored at the end of each cycle

⇨ **Recycling without separation of Cm from Am is favoured**

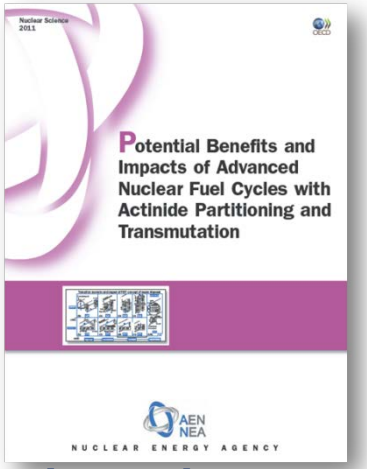
Advanced Fuel Cycles with P&T

Potential Benefits and impacts of advanced NFC with actinides P&T

❑ *Comparative analysis*

- Potential impact of P&T
- Different types of geological repositories
- Various licencing and regulatory environments
- Help shape decisions on options for advanced FC

June 2011

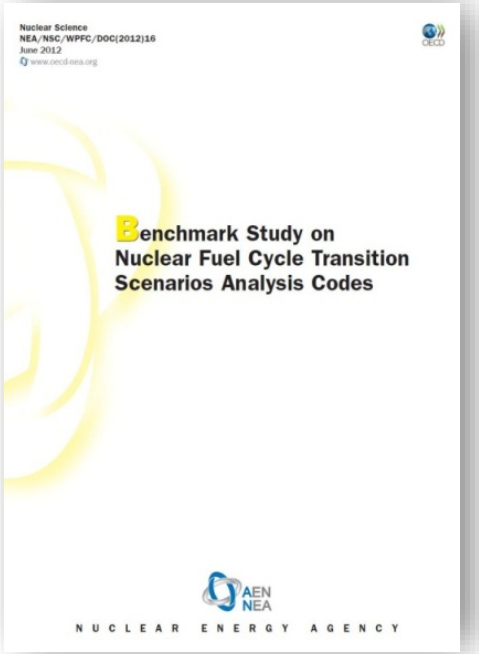


Key messages

- P&T can reduce radioactive waste management burden
  → Significant impact on repository.
- Reduction in long term radioactivity can make the uncertainty about the repository performance less important for both normal and disruptive scenarios.
- P&T will not eliminate the need for waste repositories but has the potential to *improve public perception* regarding the ability to effectively manage radioactive waste by reducing TRU waste to be disposed of.

Advanced Fuel Cycle Scenario Studies

Benchmark Study on Scenario Codes



Objectives

- ✓ Compare existing scenario codes from Belgium, Canada, France, Germany, Italy, Japan, Spain and USA
- ✓ In depletion-only calculation and in a transition scenario between Gen II to GEN IV with MA transmutation in FR

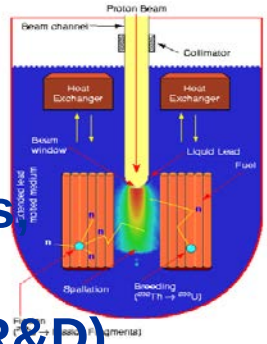
Main findings

- ✓ Very good coherency in the depletion calculation (as expected)
- ✓ Sharper differences in the dynamic scenario, due to different physical models and heterogeneity in the modeling flexibility, especially for Fast Reactors (*i.e.* the first load batches)

Accelerator Driven Systems

- **Potential option for transmutation, not to generate electricity in a competitive manner**

- **Workshop on Technology and Components of Accelerator Driven Systems (TCAD)**



- 2nd workshop was held in May 2013 (Nantes, France)
- Technical sessions: current ADS experiments, accelerators
- Simulations, safety, data, neutrons sources
- Several presentation related to MYRRHA project (project, R&D)

Next edition to be held in 2016-2017 – first two editions were held in Europe

Next edition in Japan?

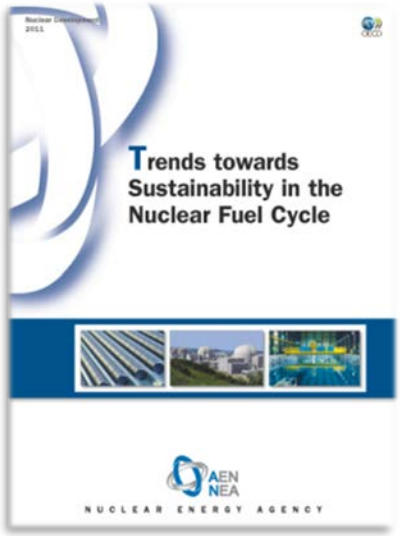
Actinides and Fission Product Partitioning and Transmutation (IEMPT)

Forum to present and discuss scientific and strategic state-of-the-art developments in the field of P&T:

- ✓ **Fuel cycle strategies and transition scenarios**
- ✓ **Radioactive waste forms and waste management strategies**
- ✓ **Transmutation (fuels and targets, physics, systems design and performance)**
- ✓ **Advances in pyro and aqueous separation processes**
- ✓ **Impact of P&T on the fuel cycle: fabrication, handling and transportation of transmutation fuels**
- ✓ **Economics of P&T**

- **12th IEMPT was held in Prague, Czech Rep., Sep. 2012**
- **13th IEMPT will be held in Seoul, Rep. Korea, 23-26 Sept. 2014**

Trends towards sustainability in the nuclear FC



Focus on:

Technical Progress

- ✓ **Chronological assessment of technology changes**
  - **developments over the last ten years**
  - **potential changes, in the near and longer term**

Trends

- ✓ **In technology, country policies & global effort**
- ✓ **Impact of technology trends on sustainability**
  - **environment, resource utilization, waste management, infrastructure, proliferation resistance and physical protection, safety, economics**

'Trends' Findings

- New build & prospects of growth (could slow-down post Fukushima)
- Prevalence of OFC, with some partial recycling for existing fleet and NPPs under construction
- U demand from non-OECD countries expected to impact OECD countries
- Increased U prices & price volatility but no short-term constraints from shortage of resources
- Yet – need for investments and timeliness of mining projects
- Little incentive to close the fuel cycle (from a resource utilisation perceptive)
- Overall only incremental progress towards sustainability
  - e.g. increasing output: higher load factors, burn-up & upratings
- Step changes in sustainability linked to deployment of Advanced FCs
  - Needed changes not market-driven ➡ government action required
- Increased weight of global strategies (IFNEC, GENIV, INPRO) & international approaches (e.g. fuel banks, regional repositories)

'Trends' Recommendations

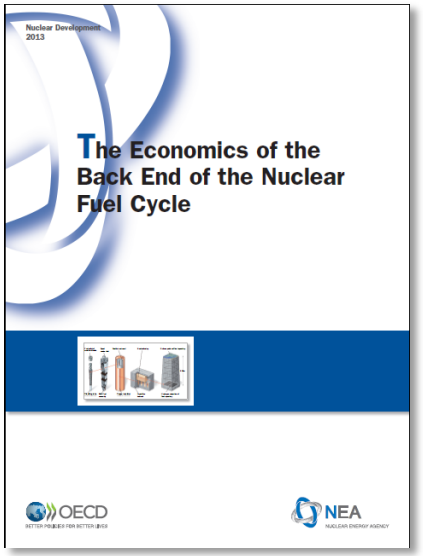
- **To support nuclear development governments would need to:**
  - ensure efficiency in necessary approval processes
  - ensure long term security of supply (from conventional & unconventional sources)
  - consider coupling energy policies with supporting fiscal policies (& market incentives) to assist risk management, particularly for the implementation of new technologies with long lead times
  - work with mining industry to ensure application of best practices
- **Waste management - Progress towards implementation of deep geological repositories must remain a high priority**
  - further R&D to optimise geological disposal solutions and to address issues related to prolonged interim storage of spent fuel
  - challenges such as licensing, public acceptance, knowledge retention must be addressed
- **Advanced reactors and closed fuel cycle**
  - Governments need to ensure adequate regulatory frameworks & resources to enable transition to fast neutron systems
  - On-going R&D and international cooperation in advanced FC should be further promoted
- **Integrated approach to the analysis of the economy of the fuel cycle (from mining to waste management) needs to be further developed**

Economics of the back-end of Nuclear Fuel Cycle (1)

- **Report "Trends towards sustainability in the Nuclear Fuel Cycle" focus on policies and strategies (2011)**
- **Analysis of economics of nuclear power across the nuclear fuel cycle in context of electricity markets, social acceptance, and technological advances**

Objectives

- Understand **economics issues and methodologies** for management of SNF
- Assess available knowledge from countries on the **costs of various options** for long-term management and disposal of radioactive wastes and **compare the cost estimates of different countries on a common basis.**
- Evaluate the impact of uncertainties

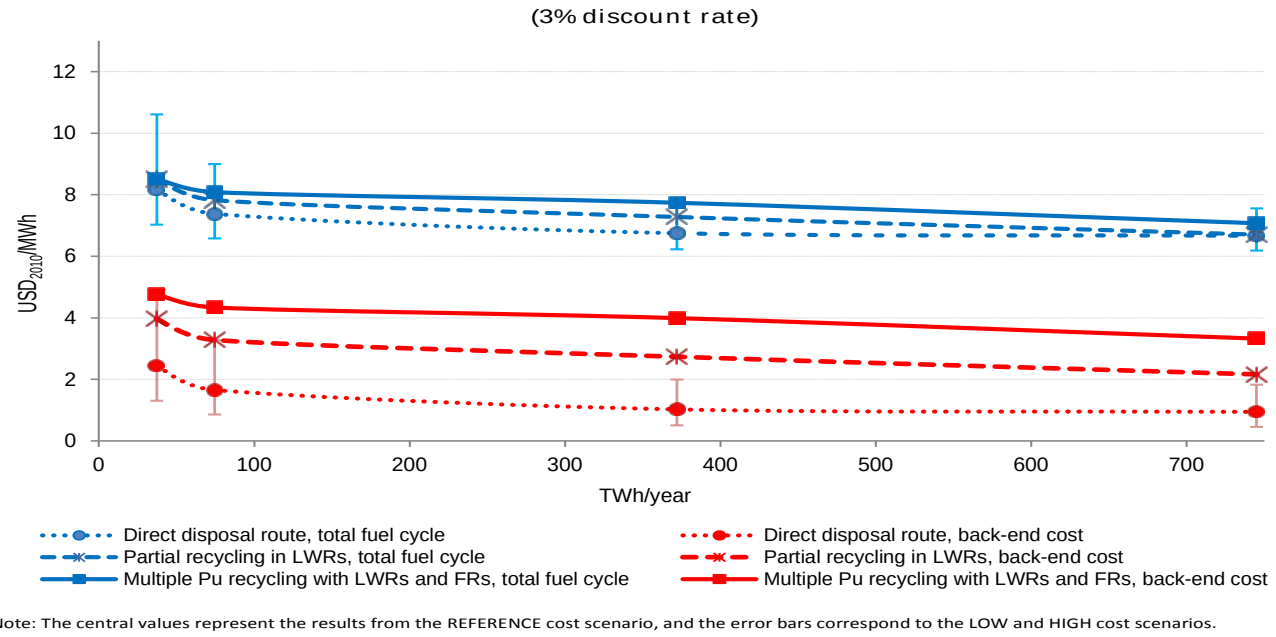


September 2013

Economics of the back-end of Nuclear Fuel Cycle (2)

- ✓ *Descriptive review*
- ✓ *Quantitative part*
- ✓ *Influence of qualitative parameters*

$LCOE_{Fuel\ cycle}$ and $LCOE_{Back\text{-}end}$ for different reactor fleets and back-end strategies



Note: The central values represent the results from the REFERENCE cost scenario, and the error bars correspond to the LOW and HIGH cost scenarios.

costs calculated for the open FC option are lower than for the other idealised options assessed. However, differences of **$LCOE_{Fuel\ cycle}$ for the three options are within the uncertainty bands**.

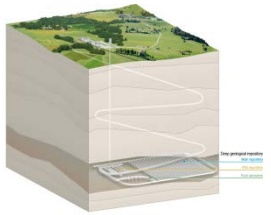
Economics of the back-end of Nuclear Fuel Cycle (3)

Main conclusions

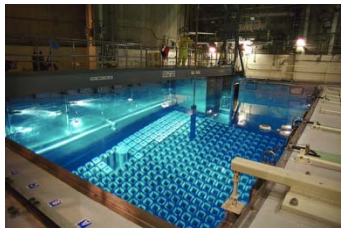
- There is the **need for a repository** (whatever option chosen- direct disposal or partial recycling).
- **Progress in the implementation of a Deep Geological Repository** are being made in some countries.
- **Assessment of cost is essential.** Difference between individual assessment can be large and depend on factor such as technical solutions and national conditions.
- It is important that financial arrangements are established.
- **Cost needs to be reviewed regularly** taking into account new technical knowledge and actual fund development
- Sensitivities analysis show that in all strategies, the total fuel cycle cost is most **sensitive to the cost of fresh UOX fuel**.
- **Political issues, social and technical aspects** need to be taken into consideration

Economics of the back-end of Nuclear Fuel Cycle (4)

Recommendations



- Government should **maintain effort in implementation of DGR.**
- **Public involvement** in SNF management strategy **is vital**
- **Ensuring funding is essential** to ensure financial provisions
- **Comparisons of fuel cycle strategies** should be made on the basis of the full fuel cycle cost.
- **Multi criteria approach** should be adopted at national level.
- **R&D on advanced NFC** should be supported by governments
- **International collaboration** and sharing experience should continue.



Concluding Remarks

- Despite impact of Fukushima, there remains a high level of interest in continued development of advanced nuclear systems and fuel cycles
  - better use of natural resources
  - minimisation of waste and reduction of constraints on deep geological repositories
- Ambitious R&D programmes on-going at national level in many countries, also through international projects
- International cooperation is an asset for maintaining, developing and gaining further knowledge and insights of scientific, technological and strategic issues associated to NFC
- NEA carries out numerous and various activities related to advanced nuclear fuel cycle and Partitioning & Transmutation
  - Scientific, economic and strategic
  - Cover all aspects of the fuel cycle: separation, fuel fab., recycling, waste managt
  - ADS
- OECD/NEA will continue to support member countries in field of fast reactor development and related advanced fuel cycles
  - forum for exchange of information
  - collaborative activities

http://www.oecd-nea.org/

Thank you for your attention