Overview of NEA activities on Advanced Fuel Cycle Scenarios

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NEA background

Nuclear Energy Agency (NEA) is an intergovernmental agency that facilitates cooperation among countries with advanced nuclear technology infrastructures to seek excellence in nuclear safety, technology, science, environment, and law. The NEA is under the framework of the Organisation for Economic Co-operation and Development.

The NEA's mission is:

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

Member countries

As of May 2016

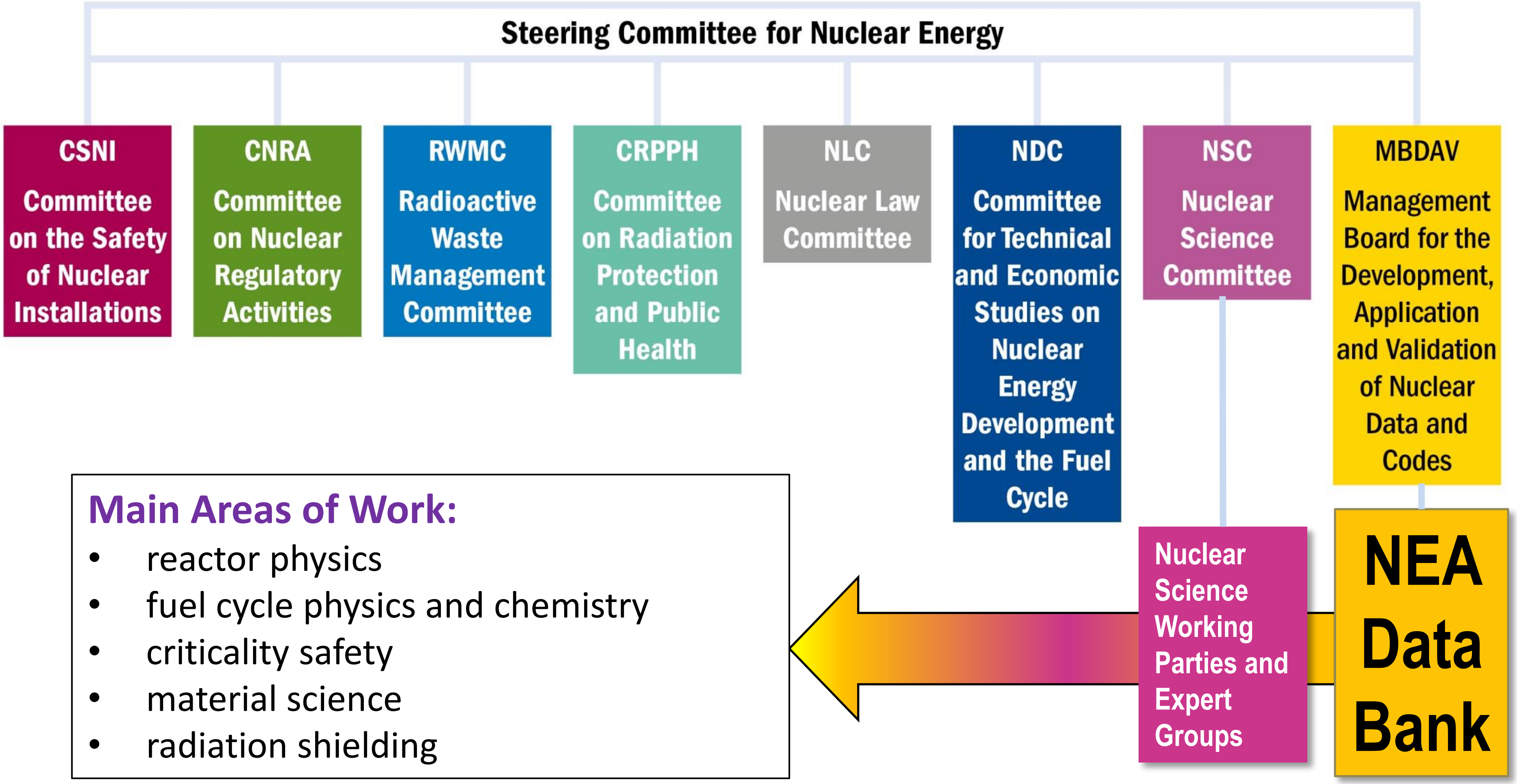
Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Japan
Korea
Luxembourg
Mexico
Netherlands
Norway
Poland
Portugal
Russia
Slovak Republic
Slovenia
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

Strategic partners

China
India

The NEA's current membership consists of 31 countries in Europe, North America and the Asia-Pacific region, accounting for ~86% of the world's installed nuclear capacity (1/5 of the electricity produced in NEA countries).

NEA Committees



Steering Committee for Nuclear Energy

CSNI
Committee on the Safety of Nuclear Installations

CNRA
Committee on Nuclear Regulatory Activities

RWMC
Radioactive Waste Management Committee

CRPPH
Committee on Radiation Protection and Public Health

NLC
Nuclear Law Committee

NDC
Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle

NSC
Nuclear Science Committee

MBDAV
Management Board for the Development, Application and Validation of Nuclear Data and Codes

Nuclear Science Working Parties and Expert Groups

NEA Data Bank

Main Areas of Work:

- reactor physics
- fuel cycle physics and chemistry
- criticality safety
- material science
- radiation shielding

Nuclear Science Committee (NSC)

Expert Group on Improvement of Integral Experiments Data for Minor Actinide Management (EGIEMAM-II)

Expert Group on Multi-physics Experimental Data, Benchmarks and Validation (EGMPEBV)

Expert Group on Accident-tolerant Fuels for LWRs (EGATFL)

Working Party on International Nuclear Data Evaluation Co-operation (WPEC)

- High Priority Request List for Nuclear Data

Working Party on Scientific Issues of the Fuel Cycle (WPFC)

- Heavy Liquid Metal Technologies
- Fuel Recycling Chemistry
- Advanced Fuel Cycle Scenarios
- Innovative Structural Materials
- Innovative Fuels
- Benchmarking of Thermal-hydraulic Loop Models for Lead-alloy-cooled Advanced Nuclear Energy Systems

Working Party on Multi-scale Modelling of Fuels and Structural Materials for Nuclear Systems (WPMM)

- Validation and Benchmarks of Methods
- Multi-scale Modelling Methods
- Structural Materials Modelling
- Multi-scale Modelling of Fuels
- Primary Radiation Damage

Working Party on Nuclear Criticality Safety (WPNCS)

- Advanced Monte Carlo Techniques
- International Criticality Safety Benchmarks Evaluation Project
- Criticality Excursions Analyses
- Assay Data of Spent Nuclear Fuel
- Uncertainty Analyses for Criticality Safety Assessment

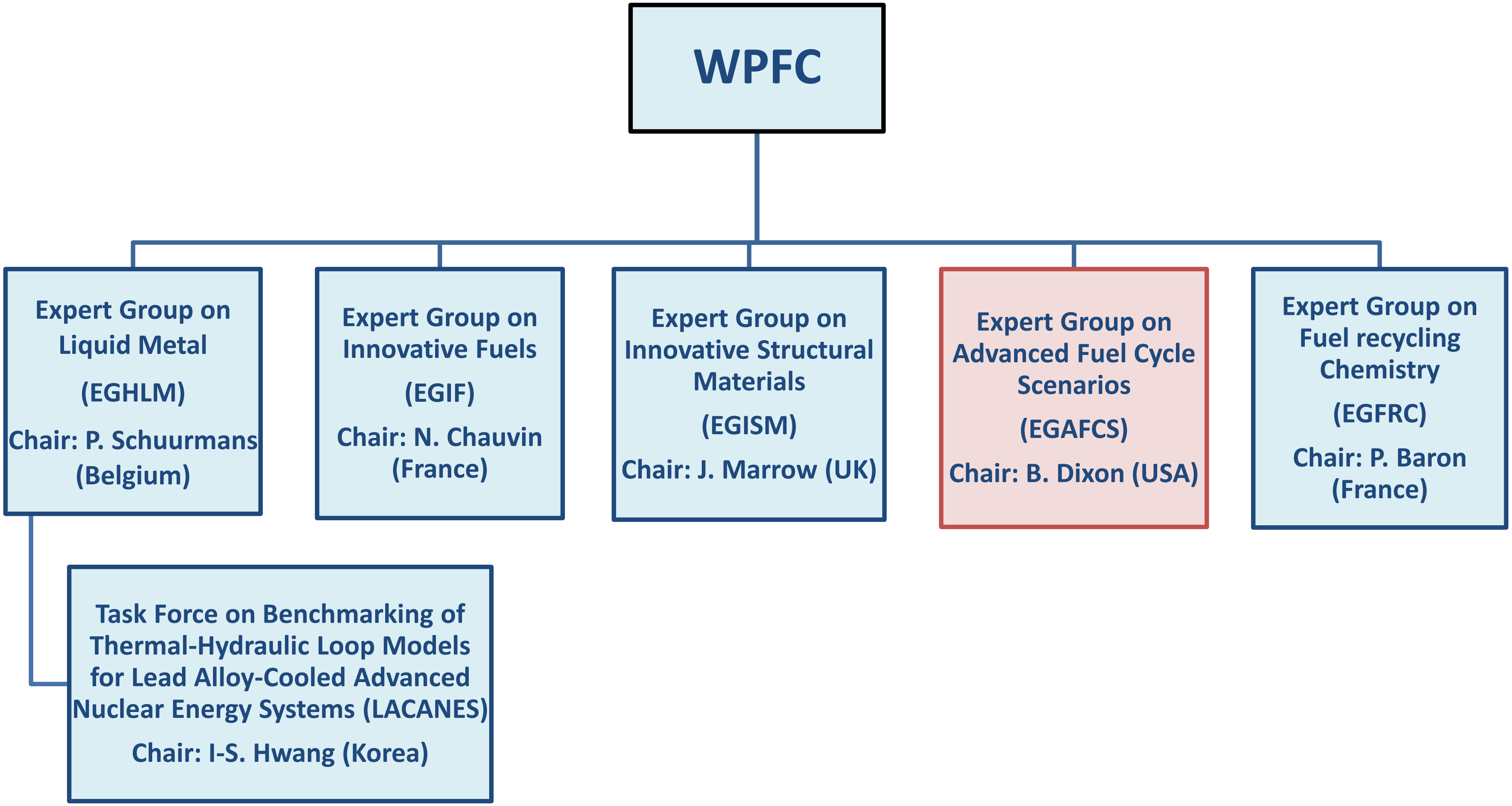
Working Party on Scientific Issues of Reactor Systems (WPRS)

- Reactor Physics and Advanced Nuclear Systems
- Uncertainty Analysis in Modelling
- Reactor Fuel Performance
- Radiation Transport and Shielding

NEA joint project in the nuclear science area:

Thermodynamics of Advanced Fuels – International Database (TAF-ID) Project

Working Party on Scientific Issues of the Fuel Cycle



WPFC

Expert Group on Liquid Metal
(EGHLM)
Chair: P. Schuurmans (Belgium)

Expert Group on Innovative Fuels
(EGIF)
Chair: N. Chauvin (France)

Expert Group on Innovative Structural Materials
(EGISM)
Chair: J. Marrow (UK)

Expert Group on Advanced Fuel Cycle Scenarios
(EGAFCS)
Chair: B. Dixon (USA)

Expert Group on Fuel recycling Chemistry
(EGFRC)
Chair: P. Baron (France)

Task Force on Benchmarking of Thermal-Hydraulic Loop Models for Lead Alloy-Cooled Advanced Nuclear Energy Systems (LACANES)
Chair: I-S. Hwang (Korea)

Expert Group on Advanced Fuel Cycle Scenarios (AFCS)

B. Feng, ANL
B. Carlier, V. Leger, AREVA
D. Wojtaszek, B. Hyland, G. Edwards, CNL
M. Tiphine, D. Freynet, C. Coquelet-Pascal, R. Eschbach, CEA
F. Álvarez-Velarde, M. García Martínez, CIEMAT
A. Brolly, EK
G. Glinatsis, F. Rocchi, ENEA
B. Dixon, INL
A. Ohtaki, K. Ono, JAEA
B. Vezzoni, F. Gabrielli, A. Rineiski, A. Schwenk-Ferrero, V. Romanello, KIT
E. Malambu, SCK·CEN
T. Viitanen, VTT
S. Cornet, OECD/NEA

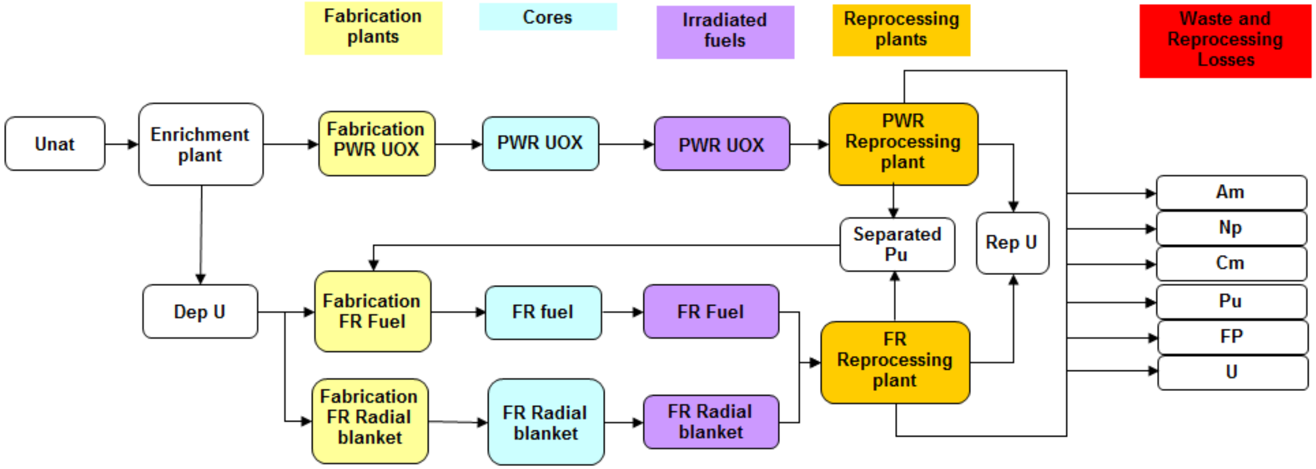
Expert Group on Advanced Fuel Cycle Scenarios (AFCS)

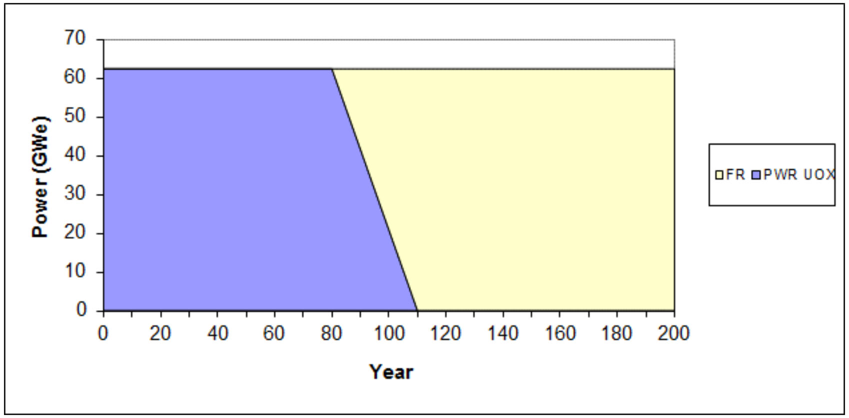
Objectives and achievements

- ➢ To assemble, organize and understand the scientific issues of advanced fuel cycles.
- ➢ To provide a framework for assessing specific national needs related to implementation of advanced fuel cycles.

- **12 meetings have been organised since 2010**
- **Two reports published:**
  - ➢ **Transition Towards a Sustainable Nuclear Fuel Cycle**
  - ➢ **Benchmark Study on Nuclear Fuel Cycle Transition Scenarios Analysis Codes**
- **Benchmark study on the effects of uncertainties of input parameters on nuclear fuel cycle scenarios studies (report being edited-to be published in 2016)**

The Effects of the Uncertainty of Input Parameters on Nuclear Fuel Cycle Scenario Studies





The Effects of the Uncertainty of Input Parameters on Nuclear Fuel Cycle Scenario Studies

Sensitivity studies		PWR UOX	FR	Expected results
General scenario assumptions				
Total nuclear energy demand	TWh/yr	430, incr., decr.	430, incr., decr.	All
Minimum cooling time	yr	2, 5, 8	2, 5, 8	SF storage and reprocessing
Fabrication time	yr	1, 2, 3	1, 2, 3	Fuels fabrication
Introduction date of FR	yr		year 70, year 80, year 90, year 130	All
Rate of introduction	yr		over 20 years, over 30 years, over 40 years	All

The Effects of the Uncertainty of Input Parameters on Nuclear Fuel Cycle Scenario Studies

Sensitivity studies		PWR UOX	FR	Expected results
Reactor characteristics				
Fissile burn-up	GWd/tHM	40, 50, 60	100, 115, 136	U consumption, enrichment, fabrication, Pu for fab., reprocessing
Fresh fuel U-235 enrichment	%	4.95 (adjusted)		
Equivalent Pu content	%		13.8 (adjusted)	
Cycle length	EFPD	410 (adjusted)	340 (adjusted)	
Breeding gain	-		0.9, 1, 1.1	Pu inventory
Reactor lifetime	yr	Infinite, 40, 60	Infinite, 40, 60	All

The Effects of the Uncertainty of Input Parameters on Nuclear Fuel Cycle Scenario Studies

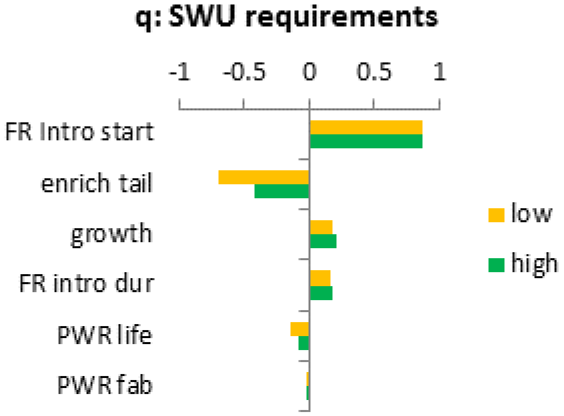
Sensitivity studies		PWR UOX	FR	Expected results
Facilities				
First year of reprocessing	yr	35, 45, 55	85, 95, 105	Storage and reprocessing
Annual reprocessing capacity	tHM	700, 850, 1000	400, 600, 800	Storage and reprocessing
Losses (U, Pu)	%	0.05, 0.1, 0.2		Waste
Enrichment tail	%	0.15, 0.25, 0.35		Enrichment, U consumption
MA recycling				
Initial MA weight content	%	-	0, 1, 2	MA storage and inventory
Recuperation rate (MA)	%	-	0, 99.9, 99	Waste

The Effects of the Uncertainty of Input Parameters on Nuclear Fuel Cycle Scenario Studies

Example Results

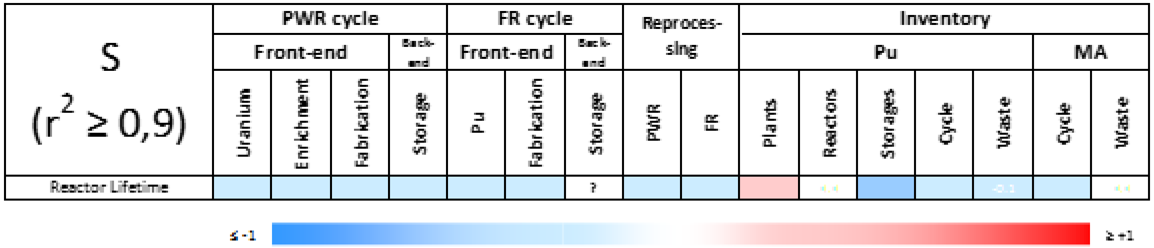
Tornado diagrams

$$q = \frac{p_{ref}(R_{ref} - R_s)}{R_{ref}(p_{ref} - p_s)}$$



Sensitivity table

$$S = \frac{p_{ref}}{R_{ref}} \cdot \frac{\partial R}{\partial p}$$



S ($r^2 \geq 0{,}9$)	PWR cycle				FR cycle			Reproces-sing		Inventory						
	Front-end			Back-end	Front-end		Back-end			Pu					MA	
	Uranium	Enrichment	Fabrication	Storage	Pu	Fabrication	Storage	PWR	FR	Plants	Reactors	Storages	Cycle	Waste	Cycle	Waste
Reactor Lifetime							?				[illegible]			-0.1		[illegible]

≤ -1 ≥ +1

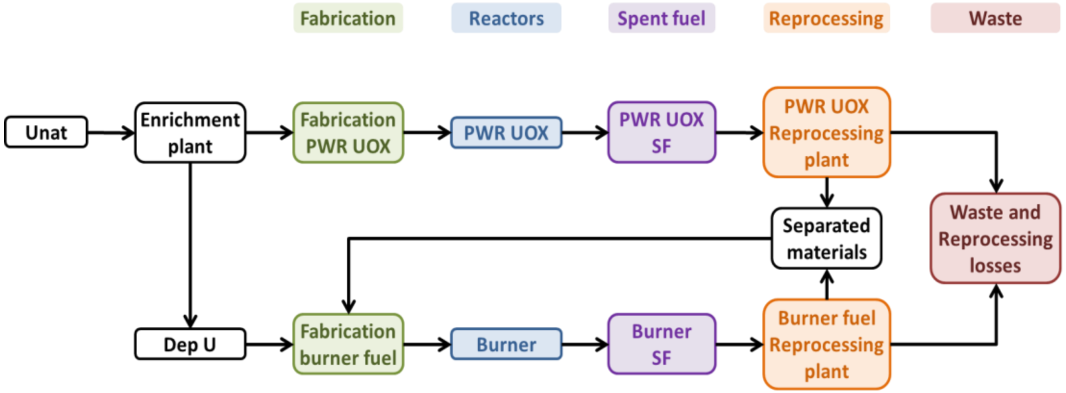
Benchmark on TRU management scenarios

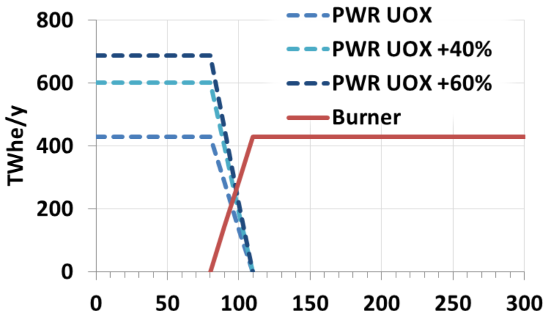
Benchmark objectives

- Compare codes and models;
- Evaluate how much of the materials in spent fuel can be burnt with different “burner fleets”;
- Assess the possibility of going back to an equilibrium state after the reduction of the TRU stocks.

Three steps scenarios:

- Step 1: equilibrium PWR UOX fleet
- Step 2: reduction of the TRU inventories with a burner fleet
- Step 3: evolution toward a sustainable state (e.g. stabilization of the Pu inventory).





Expected Results

Reactors:

- Pu, Am, Np, Cm and MA contents (wt%)
- Pu, Am, Np, Cm and MA balances (kg/TWhe)

Enrichment plant:

- Natural uranium consumption (t and t/y)
- Enriched uranium need (SWU and t/y)

Fabrication and reprocessing plants:

- Annual flow (t/y)
- Pu, Am, Np, Cm annual flows (t/y)
- Activities (Bq and Bq/t)
- Radiotoxicity (Sv and Sv/t)
- Decay heat (W and W/t)

Separated materials storage:

- Stored mass for each separated material (t)

Material transportation:

- Annual flow (t/y)
- Neutron emissions (n/s and n/s/t)
- Decay heat (W and W/t)

Disposals:

- Mass of waste (t)
- Long term radiotoxicity of waste accumulated at the end of the scenario (Sv, over 1.10^6 years)

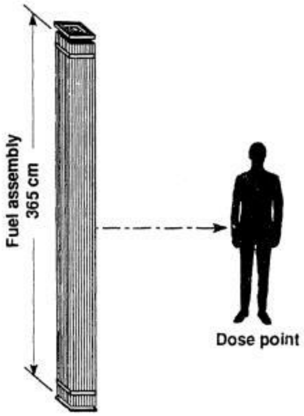
Inventories:

- Pu, Am, Np, Cm and MA inventories in cycle (t)
- Pu, Am, Np, Cm and MA inventories in waste (t)
- Pu, Am, Np, Cm and MA total inventories (t)

Benchmark study on Dose rate calculation for irradiated fuel assembly

Background:

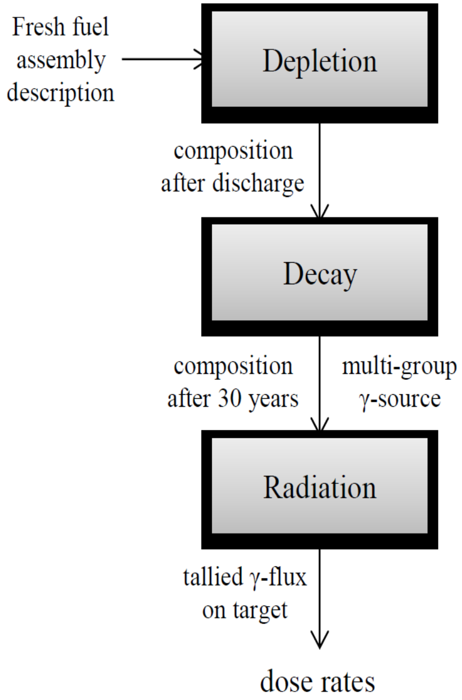
- Comparative study conducted by DOE and CEA → verify gamma dose rate calculation methodology, especially for cases in which quantitative measurements of proliferation resistance are desired.
- The accepted code for dose rate calculations (Microshield) was primarily intended for shielding design, where dose overestimation is conservative. For self-protection calculations, dose underestimation is conservative.
- Preliminary calculations on 30-year aged spent fuel assemblies with updated methods and codes predicted dose rates roughly three times lower.
- Accurate predictions of this dose rate after decades of cooling depend on factors such as the assembly's power history, composition, and geometry as well as the calculated gamma source and radiation deposited on the target.
- In addition to gamma transport calculations, the depletion, decay and gamma source calculation approaches need to be precisely carried out.



Benchmark study on Dose rate calculation for irradiated fuel assembly

Objectives:

Verify updated dose rate calculation procedures (new modeling approaches, new nuclear data, new versions of the codes) **and to share the benchmark results at the international level**



Fresh fuel assembly description
Depletion
composition after discharge
Decay
composition after 30 years
multi-group γ-source
Radiation
tallied γ-flux on target
dose rates

Two parts:

- ✓ Verification (comparison of results with different codes/methodologies)
- ✓ Validation (comparison of results with experimental data, if available)

- 9 institutions take part in the activity (ANL, AREVA, CIEMAT, CEA, CNL, ENEA, KIT, VTT, SCK-CEN)
- Timeline: ~18 months

Conclusions

- The NEA Expert Group on Advanced Fuel Cycle Scenarios (AFCS) carries out numerous and various activities related to the aspects of the transition between a current fuel cycle scenario and an advanced one.
- It cover all aspects of the fuel cycle scenario analysis: current and advanced reactors, separation, fuel fabrication, recycling, waste management.
- International cooperation is an asset for maintaining, developing and gaining further knowledge and insights of scientific, technological and strategic issues associated to the nuclear fuel cycle.
- A framework for assessing the scientific issues of advanced fuel cycles has been successfully provided.

Thank you for your attention