PRESENTATION OF THE EUROPEAN PROJECT PUMMA DEVOTED TO PLUTONIUM MANAGEMENT IN THE WHOLE FUEL CYCLE

FISA 22 conference, Lyon,

30 May – 3 June

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PuMMA
Plutonium Management for More Agility

This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 945022.

Plutonium Management for More Agility

CONTEXT

- **Federate the European community on MOX fuel around the challenges of advanced reactors (GENIV) and advanced fuel cycle.**

OBJECTIVES

- **Plutonium management in 4th generation reactors (SFR, GFR, LFR, ADS) → impact on fuel behavior, core safety, reprocessing and all the fuel cycle parameters.**

- **Experimental results & calculations on MOX pins** during representative **nominal conditions and**
during accidental conditions that can lead to fuel melting and clad failure.

- Comparison of experimental irradiation in Material Testing Reactor (**MTR**) with the results of an irradiation in representative a fast neutron reactor (**SFR**).

- **Education & training** : maintain the expertise and the skills on the management of Pu in Europe involving young generation of researchers with the experts who had contributed to these projects : the CAPRA program, the EFTTRA group, the ADS community and the GIF and a lot of associated European projects over the last 30 years.

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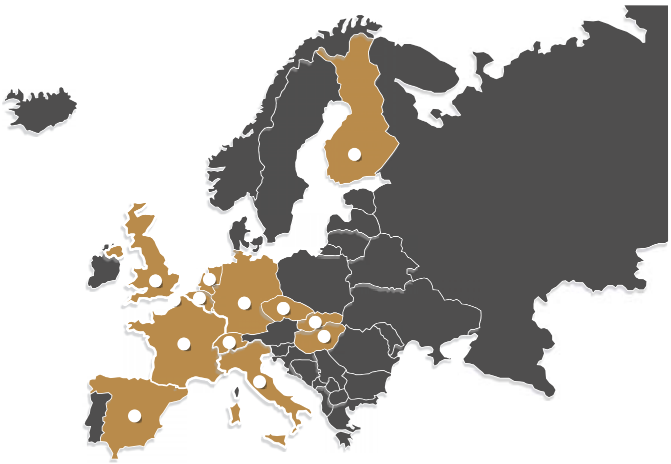
The PuMMA consortium



Belgium
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Slovakia
- VUJE

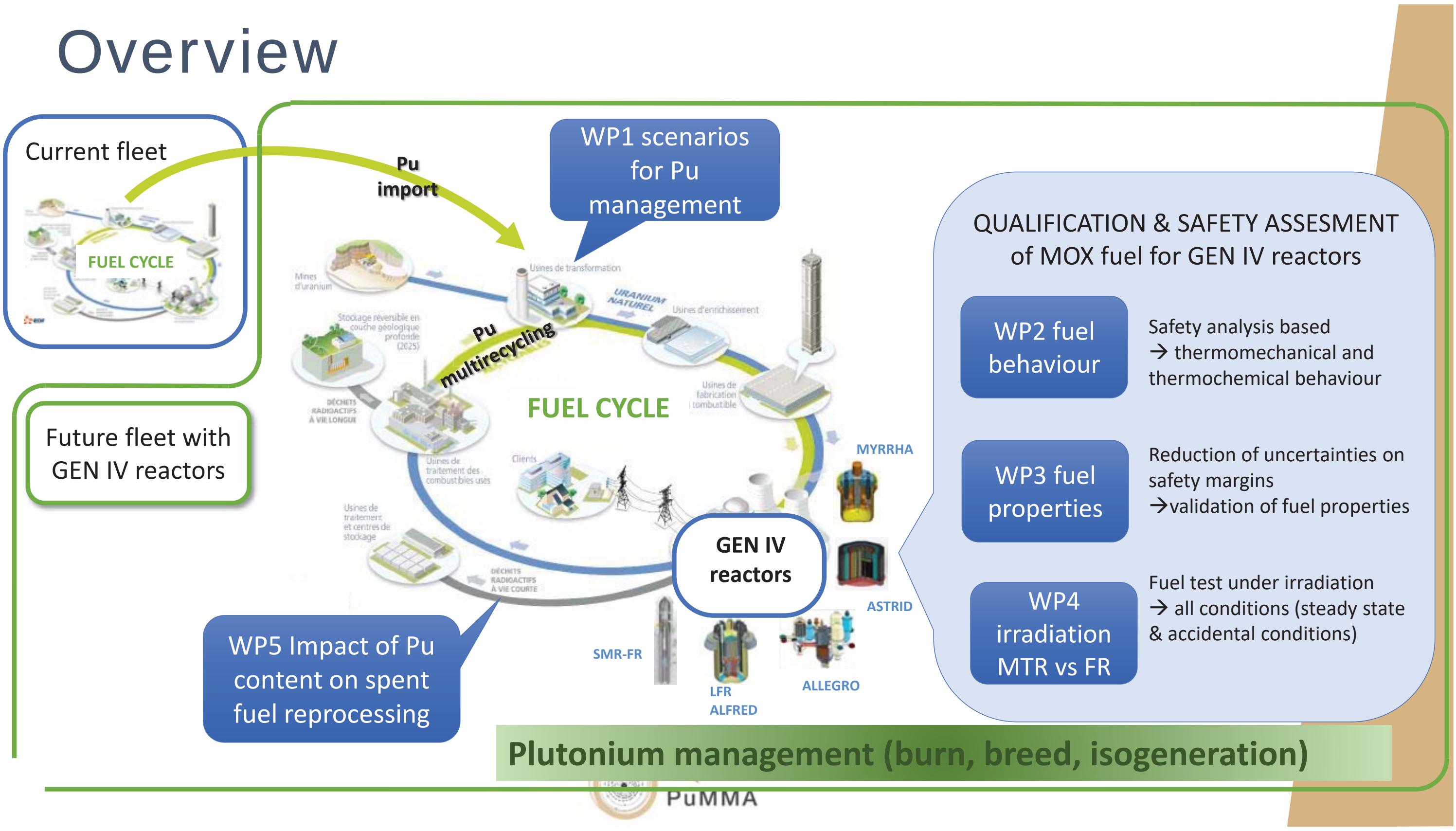
Switzerland
- EPFL
- PSI

Spain
- CIEMAT

United Kingdom
- NNL
- JACOBS

BUDGET : E.U. FUNDINGS = 3,8 M€ TOTAL = 7M€

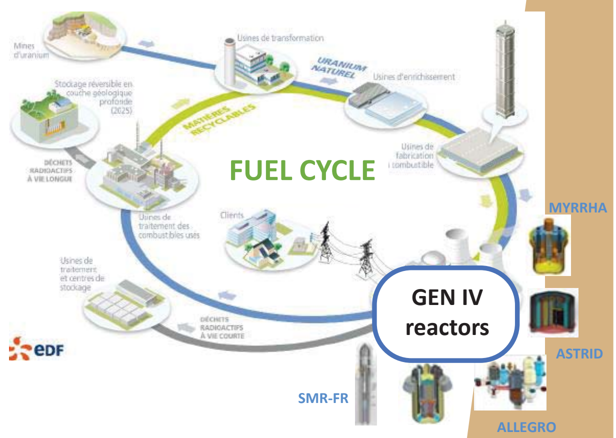
Overview



WP1 Study of plutonium management in connection with the fuel cycle : scenario studies

OBJECTIVES

- Highlight the flexibility of the GEN-IV reactors on the management of the plutonium: breeder, burner, isogeneration. Performances and impact on fuel cycle and reactor.
- Consideration of the transition scenario from LWR to fast GEN-IV reactors to evaluate the plutonium to be taken into account in fast reactor fuels: composition and isotopy.
- Study of the impact on all operations of the cycle: manufacturing, storage, transportation, reprocessing, core design, fuel behavior. Economic impact.
- Sensibility studies with uncertainty propagation



WP1 Study of plutonium management in connection with the fuel cycle : scenario studies

RESULTS ACHIEVED

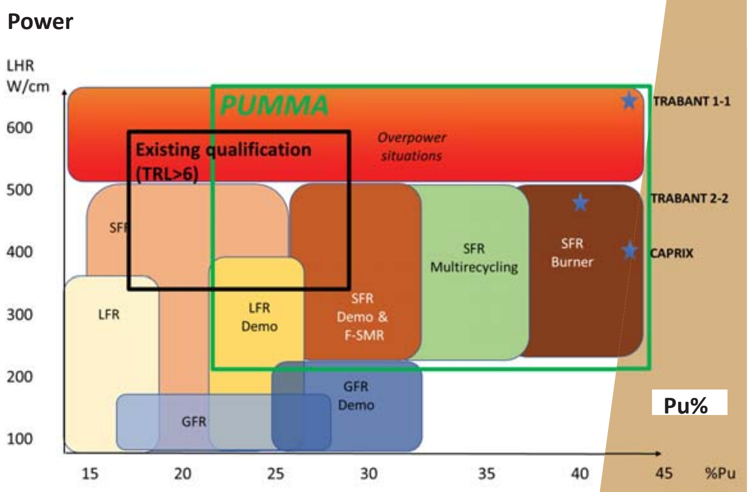
- Definition of input data regarding the reactors for the scenario studies
- Selection of the scenarios to be studied

Deliverables
D1.1 Report on Input Data of GenIV reactors is a confidential report led by BME produced and delivered at M12. It includes the general information and appropriate references of the Gen-IV reactors that will be used in the rest of the WP1 tasks. These reactors include the ESFR, ELSY, ALFRED, GFR and ALLEGRO critical reactors and the EFIT subcritical system. Burner, breeder and isogeneration versions are included for some of these reactors, in particular ALFRED and ESFR. The information contained for each particular design includes the thermal power, the efficiency, the fuel/cladding/coolant materials, the Pu enrichment and the actinide mass at the beginning of the irradiation, the number of fuel assemblies, the average burn-up and the irradiation time. This information has been gathered from the references and the participation of some of the PUMMA partners in other projects, excepting for the case of the ESFR and ALFRED burner versions, specifically developed for this task.

WP2 Qualification Of Mox Fuel Behaviour For GenIV Systems

Objectives

- Extend fuel qualification for high Pu%
- Extension of validation domain of FPC with 3 irradiations of the same fuel (45%Pu) irradiated in MTR (nominal and overpower) and in SFR (nominal):
  - calculations with fuel performance codes
  - post irradiation examinations
- Methodology for safety analysis of fuel pins with high plutonium content.



New approach

- Starting with a benchmark exercise in order to define the PIE programme for the validation of FPC.

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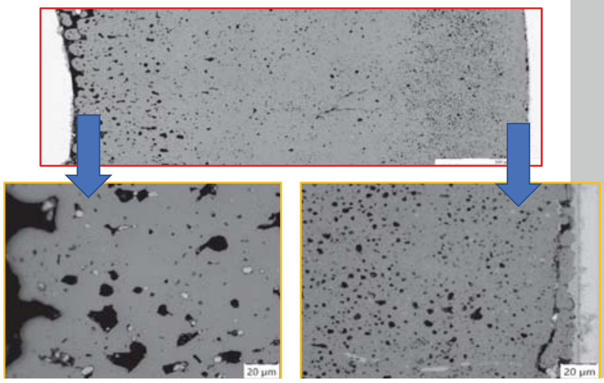
WP2 Qualification Of Mox Fuel Behaviour For GenIV Systems

Results achieved

- Irradiation conditions of CAPRIX, TRABANT1, TRABANT2
- Starting benchmark with several Fuel Performance Codes
- 3 PIE programmes with schedules

CAPRIX MOX at 45Pu%, L. Fayette CEA-LECA



Deliverables
D2.1.1 is a confidential report on CAPRIX irradiation conditions in PHENIX produced and delivered at M12, led by NRG. The CAPRIX pins were irradiated in PHENIX from 49th to 53rd cycle. The characteristic neutronic and thermal-hydraulic quantities of the irradiation were realized with the Monte Carlo code TRIPOLI4 and the thermal-hydraulic code TRIO MC.
D2.1.2 is a confidential report on TRABANT 1 pin 1 irradiation conditions in HFR produced and delivered at M12, led by NRG. The irradiation of TRABANT-1 pin 1/1 was performed during 12 HFR cycles that was divided into two sets of 6 reactor cycles of approximately ~30 days each.
D2.1.3 is a confidential report on TRABANT2 pin 2 irradiation conditions in HFR produced and delivered at M12, led by NRG. The TRABANT-02 experiments, containing the pin of interest for this study (pin 2/2), started irradiation in November 2001 and proceeded for two cycles: 01-11 and 01-12. After a significant delay, the irradiation continued for one more cycle in 2005 after which the irradiation was discontinued. A total of 74 Full Power Days was achieved in the HFR.

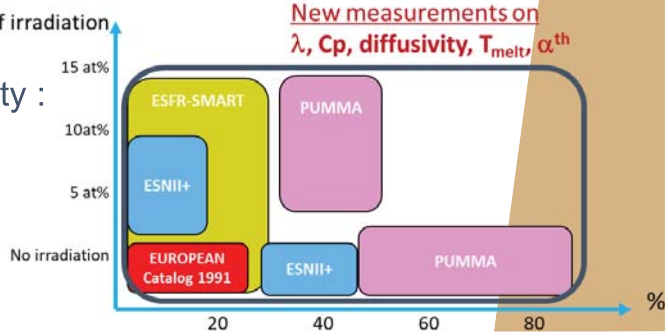
WP3 Fuel Properties With High Pu Content: Measurements and Modelling

Objectives

- Reduce uncertainty in safety evaluation by reducing uncertainties on fuel properties
- Measurements on MOX properties : λ, Cp, diffusivity, T_{melt}, α^{th} as a function of density, Pu content, O/M and burn-up on non-irradiated and irradiated fuels
- Monte Carlo calculations to determine thermal properties of MOX fuel with parameter dependency
- Thermodynamic modelling in support thermal properties evaluation
- Recommandation on mechanical properties : elastic (Young modulus, Poisson ratio) and non elastic (creep, plasticity and rupture) under steady state and accident.

New approach

- Experimental programme defined for each property :
  - Extension of validation
  - Liability of safety margins



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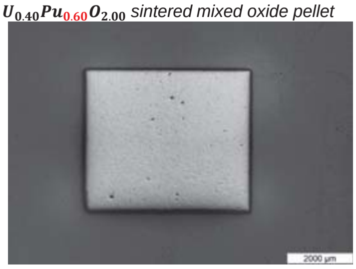
WP3 Fuel Properties With High Pu Content: Measurements and Modelling

RESULTS ACHIEVED

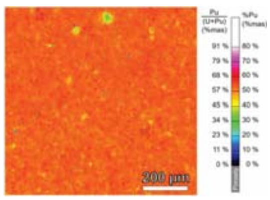
- Atomic calculations of thermal properties : start the activity with Cp=f(O/M)
- Elastic properties recommendations : start of the activity
- Experimental programme : first fabrications and characterization of MOX at 60, 65, 70 Pu%. Measurements of melting temperature of PuO_2

Optical microscopy observation of the obtained $U_{0.40}Pu_{0.60}O_{2.00}$ sintered mixed oxide pellet



Characteristics:

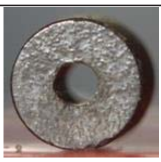
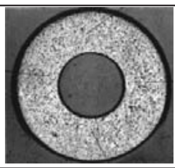
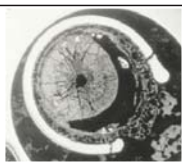
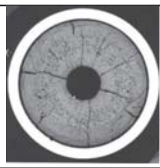
- ✓ Monophasic and stoichiometric $U_{0.40}Pu_{0.60}O_{2.00}$ mixed oxide
- ✓ Clean microstructure without cracks
- ✓ Homogeneous cationic distribution
- ✓ Dense pellet (96% of d_{theo})



Pseudo-quantitative mapping of the Pu distribution determined by Electron Probe Micro-Analysis

PhD MM. Desagulier, CEA - Atalante

WP4 Comparison of irradiation results in fast spectrum vs thermal spectrum (MTR)

FRESH FUEL	Irradiation in MTR – nominal conditions TRABANT 2	Irradiation in MTR – fuel melting + clad failure TRABANT1	Irradiation in FAST REACTOR CAPRIX
			

Objectives:

- Comparison of irradiation results in MTR and SFR
- Analysis of the advantages / disadvantages of SFRs / MTRs for future irradiation programs
- Contribution of MTR and SFR irradiations to the fuel qualification (TRL) with different irradiation devices

New approach :

- Same fuel irradiated in MTR (HFR) and FR (Phenix): comparison of results
- Contribution of MTR for off-normal condition tests.

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WP4 Comparison of irradiation results in fast spectrum vs thermal spectrum (MTR)

Results achieved

- Comparisons of pin irradiation conditions in MTR vs SFR
- Inventory of devices for experimental irradiation in MTR and SFR : new template for device characteristics

Deliverables
D4.2 Irradiation condition requirements for FR fuel qualification and the applicability of FR and MTR (preliminary version submitted M16; final version due M38) Deliverable goals and dates were modified in first phase of project, when details were discussed. This deliverable contains the boundary conditions and parameters to which the modelling efforts will be evaluated. These parameters are identified early in the project and are summarized in a preliminary version of the deliverable (could also have been a technical note, but partners indicated it felt better to put it in the deliverable). Preliminary version is completed (M16) and is formalization is underway. The deliverable will be finalized after an evaluation from the modelling efforts is included.

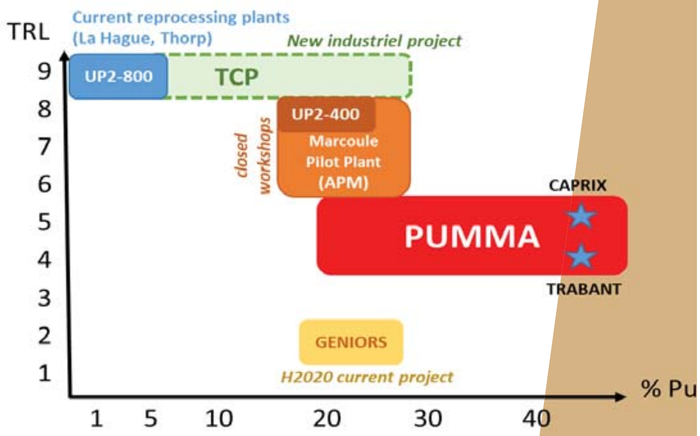
WP5 Qualification Of MOX Fuel Dissolution

Objectives:

- Extension of dissolution qualification to high Pu% spent fuel
- Dissolution test at a lab scale with irradiated CAPRIX/TRABANT fuels in order to evaluate the impact of high Pu content (>30%) on Pu dissolution rate and FP distribution in solid residues
- Dose evaluation of extractant

New approach :

- Test on fresh fuel and then on irradiated fuel for process optimisation



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WP5 Qualification Of Mox Fuel Dissolution

RESULTS ACHIEVED

- Definition of experimental tests conditions on fresh and irradiated fuels at CEA-Atalante (MOX at 45%Pu fresh and irradiated CAPRIX) and NNL (MOX powders)
- Several tests achieved, results to be interpreted

Non irradiated CAPRA pellets after dissolution. CEA-Atalante

Deliverables
D5.1 – Coordination of Pu-active and HA dissolution experiments (NNL, CEA, NRG) has been completed. The report summarises discussion between CEA, NRG and NNL to maximise commonality between experiments that will maximise comparability.

WP6 Education and training, dissemination and communication

Objectives:

- To encourage mobility of PhD students, post-doc...;
- To organize workshops for PhD students, post-docs, researchers, designers, stakeholders, etc.;
- To improve educational tools and learning methodologies;
- To disseminate the outcomes of the project to a larger audience

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WP6 Education and training, dissemination and communication

Results achieved

- Identify the first secondments
- MOOC production – discussions about the format
- Database of courses: identify relevant past projects and workshops or seminars
- PUMMA workshop 1 on Fuel Cycle Scenarios held in Madrid
- Dissemination & communication

Euratom funded projects on fuel, reprocessing and fuel cycle scenarios					
Project No	Framework Programme	TOPIC	Project Acronym	Project Title	Start Date
1	FP6-EURATOM-NUWASTE - Thematic priority - Management of radioactive	NUWASTE-2003-3.2.2.1-1 - Partitioning of actinides and fission products from high-level nuclear	EUROPART (it is the merged	EUROpean research program for the PARTitioning of minor	01/01/2004
2	FP6-EURATOM-NUWASTE - Thematic priority - Management of radioactive	NUWASTE-2004-3.2.2.1-1 - Transmutation of high-level nuclear waste in an Accelerator Driven	EUROTRANS (Its sister project of	European research Programme for the transmutation of high	01/04/2005
3	FP7-EURATOM-FISSION - EURATOM: Nuclear fission and radiation protection	Fission-2008-1.2.2 - Transmutation fuels and targets and their reprocessing	FAIRFUELS	FAbrication, Irradiation and Reprocessing of FUELS and targets for	01/02/2009
4	FP7-EURATOM-FISSION - EURATOM: Nuclear fission and radiation protection	Fission-2011-2.3.1 - R&D activities in support of the implementation of the Strategic	PELGRIMM	PELlets versus GRanulates: Irradiation, Manufacturing &	01/01/2012
5	H2020-Euratom-1.2. - Contribute to the development of solutions for the	NFRP-5 - Materials research for Generation-IV reactors	INSPYRE	Investigations Supporting MOX Fuel Licensing in ESNII	01/09/2017
6	FP7-EURATOM-FISSION - EURATOM: Nuclear fission and radiation protection	Fission-2013-2.3.1 - Support to the development of joint research actions between national programmes	MATISSE	Materials' Innovations for a Safe and Sustainable nuclear in	01/11/2013
7	FP7-EURATOM-FISSION - EURATOM: Nuclear fission and radiation protection	Fission-2007-1.2-01 - Partitioning processes for viable recycling strategies	ACSEPT	Actinide reCycling by SEParation and Transmutation	01/03/2008

Database of courses

Project Long term Results

- Demonstrate that fast reactors with the associated fuel cycle is the best way for plutonium management with flexibility and sustainability
- Provide new results for Improving the knowledge in all the steps of the fuel cycle
- Associate the new generation of researchers

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Thank you!

Contact us for more information!

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