# 1. Publishable summary

## 1.1. Summary description of project context and objectives

The PELGRIMM project addresses Minor-Actinide (MA) bearing oxide fuels for Generation IV – Sodium Fast Reactor Systems. Two options, MA homogeneous recycle in driver fuels with MA content at a few percent and heterogeneous recycle on $UO_2$ fuels bearing high MA contents located in the radial core blanket, are considered. Investigations on both kinds of MA-bearing oxide fuels, started (more or less) recently and experimental knowledge remains mostly limited to laboratory-scale fabrication processes, small amount of characterization and out-of-pile testing, as well as scarce irradiation experiments.

The project PELGRIMM aims at taking a new step in the long term process of the MA-bearing fuel qualification rationale, by investigating a wide range of items:

- from solid to sphere-packed fuel shape, the latter potentially leading to significant improvements in fuel fabrication processes and fuel performance under irradiation

- from fuel fabrication and characterization to behaviour under irradiation,

- from experiments to modelling and simulation,

- from normal operating conditions in a Sodium Fast Reactor to transients and severe accidents.

A total of 12 partners from research laboratories, universities and industries, collaborate to share and leverage their skills, progress and achievements, covering a comprehensive set of investigations, in order to:

- perform the Post-Irradiation Examinations of MARIOS and SPHERE irradiated pins within the European project FAIRFUELS, providing the very first results respectively on the helium behaviour in $(Am,U)O_2$ fuels and a comparison between sphere-packed and pelletized $(U,Pu,Am)O_2$ fuel performances;

- take the next step in the $(Am,U)O_2$ fuel qualification rationale by performing the semi-analytical test MARINE in HFR;

- extend Minor Actinide bearing fuel fabrication processes to alternative routes in order to limit secondary waste streams;

- extend the capabilities of existing calculation codes to describe the MA bearing fuel behaviour under irradiation

- accomplish a preliminary design of a sodium cooled fast reactor core with spherepacked $(U,Pu,Am)O_2$ fuels and perform a preliminary safety assessment.

PELGRIMM aims at promoting the implication of European students and young researchers too, through:

- placements of trainees in organisations involved in the project

- the development and delivery of training courses and workshops

- contributions to research actions of the project by researchers preparing a doctoral thesis or employed at a post-doctoral position.

## 1.2. Expected final results and their potential impact

At the end of the project, the first results on helium behaviour in $(Am,U)O_2$ irradiated fuels at constant temperatures will be available thanks to Post Irradiation Examinations performed on 2 MARIOS mini-pins. A first comparison between sphere-packed and pelletized $(U,Pu,Am)O_2$ fuel performances under irradiation will have been done thanks to Post Irradiation Examinations implemented on the SPHERE segments. The semi-integral test MARINE including pelletized and sphere-packed $(U,Am)O_2$ fuels as well as an on-line gas pressure record in the pins will have been completed in the High Flux Reactor. Alternative routes of Minor Actinide bearing fuel fabrication processes will have been investigated to seek for improvements (simplification, robustness, lower secondary waste streams, …). Capabilities of fuel irradiation behaviour calculation codes will have been improved thanks to the implementation of more mechanistic models, new numerical methods, more reliable properties laws, … A preliminary safety performance assessment of sphere-packed $(U,Pu,Am)O_2$ fuels in the core of a sodium fast reactor will have been performed.

Thus, the PELGRIMM project will have:

- capitalized on efforts made within the previous European projects: ACSEPT (2008-2012), FAIRFUELS (2009-2013), F-BRIDGE (2008-2012) and CP-ESFR (2008-2012);

- and taken a new step in the development of both MA-bearing fuel options: $(U,PuMA)O_2$ and $(U,MA)O_2$, related to fuel fabrication processes, irradiation behaviour and core safety performance, including a comparison on fuels shaped as pellets and beads.

## 1.3. Description of the work performed

The work within the first period addressed the first stages following the completion of the MARIOS irradiation in HFR. The capsule was dismantled. Neutron radiographies have shown that most of the $(U,Am)O_2$ samples irradiated at 800 and 1100°C during 11 months, remain in one piece. Gas punctures were performed on 3 pins. The activation monitor set in the capsule were read. Calibrated burn-up calculations taking into account of the effective irradiation history, started. When the pins are transferred from HFR to the LECA facility (currently subject to IR100 cask agreement renewal), the Destructive Examination programme will be implemented.

The semi-integral experiment MARINE in HFR on $(U,Am)O_2$ fuels shaped as beads and pellets, is being prepared. Specifications as well as the pre-design of the test are almost ready. Fuel fabrication R&D is going-on for calibrated beads and finished for pellets. An innovative device has been designed and provisioned to make easier the connection between the pin and the on-line pressure measurement equipment.

The Post-Irradiation Examination programme related to the SPHERE irradiation on $(U,Pu,Am)O_2$ fuels (shaped as beads and pellets) to be completed within the frame of the FAIRFUELS project, was drafted during the period.

The investigation of alternative processes for Minor Actinide bearing fuel fabrication started. On the one hand, the Weak Acid Resin route was successfully implemented for the fabrication of $U_{0.9}Am_{0.1}O_2$ beads. One the other hand, promising results have been gained from the implementation of the microwave technology in the internal gelation fabrication route.

Status of the code developments: GERMINAL, MACROS, SPHERE/SPACON & TRANSURANUS, describing the oxide fuel behaviour under fast neutron irradiation conditions were reviewed. Then first developments started regarding models for helium migration description, extended fuel property laws to MA-bearing fuels as well as the particularity of sphere-packed fuel geometry.

Finally, the problematic of sphere-packed fuelled core physics, design and safety performance has been tackled: a reference SFR core design (made of pelletized fuel) based on the outcomes of the PF-7 CP-ESFR project was selected. Exploratory developments have been performed to move to a preliminary sphere-packed core design.

## 1.4. Project information

Website address: **www.pelgrimm.eu**

**Project type:** Collaborative Project

**Project start date**: 01/01/2012 **Duration**: 48 months

**Total budget**: EUR 6,772,844 **EC contribution**: EUR 2,999,999

**Partners:**

| Beneficiary Number | Beneficiary name | Beneficiary short name | Country | Date enter project | Date exit project |
|---|---|---|---|---|---|
| 1 | COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES | CEA | France | 1 | 48 |
| 2 | AREVA NP SAS | AREVA | France | 1 | 48 |

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| 3 | ELECTRICITE DE FRANCE S.A. | EDF | France | 1 | 48 |
| 4 | AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE,L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE | ENEA | Italy | 1 | 48 |
| 5 | RESEAU EUROPEEN POUR L'ENSEIGNEMENT DES SCIENCES NUCLEAIRES | ENEN | France | 1 | 48 |
| 6 | JRC -JOINT RESEARCH CENTRE-EUROPEAN COMMISSION | JRC | Belgium | 1 | 48 |
| 7 | Karlsruher Institut fuer Technologie | KIT | Germany | 1 | 48 |
| 8 | KUNGLIGA TEKNISKA HOEGSKOLAN | KTH | Sweden | 1 | 48 |
| 9 | LAGRANGE SARL | LGI | France | 1 | 48 |
| 10 | NUCLEAR RESEARCH AND CONSULTANCY GROUP | NRG | Netherlands | 1 | 48 |
| 11 | PAUL SCHERRER INSTITUT | PSI | Switzerland | 1 | 48 |
| 12 | STUDIECENTRUM VOOR KERNENERGIE | SCK-CEN | Belgium | 1 | 48 |