OPEn HPC theRmomechanical tools for the development of eAtf fuels

# Deliverable D8.2 – OperaHPC: Plan for the Exploitation and Dissemination of Results

Version 1 – 26/09/2023

Funded by the European Union

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| Document type | Deliverable |
| Document number | D8.2 version 1 |
| Document title | OperaHPC: Plan for the Exploitation and Dissemination of Results |
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| Release date | 26/09/2023 |
| Contributing partners | CEA, SINTEC |
| Dissemination level | SEN |

| Version | Short description | Main author | WP leader | Coordinator |
|---|---|---|---|---|
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## Abstract

This document describes the exploitation and dissemination plan of the OperaHPC project. The later offers a large panel of objectives from basic research up to industrial safety studies trough open source code development. Consequently, the dissemination and exploitation plans have been defined to be in line with all type of expected results.

# Table of contents

# 1 Introduction

The main purpose of this deliverable is to describe the exploitation and dissemination strategies and methodologies of the OperaHPC project. This document is decomposed in three main section with a) the context and objectives of the project, b) the dissemination plan and c) the exploitation activities of the project results.

# 2 Context and objectives of the project

Electrification of the energy sector will be a key step for its transition to climate-neutrality. In order to achieve it by 2050, it will be necessary to maintain and even extend the production capacity of current nuclear reactors, while taking into account the evolving electricity mix and increasing requirements regarding the safety assessment of nuclear reactors. On these points, the question of nuclear fuel behaviour is essential because it sets the main constraints to be satisfied for safe operation of nuclear reactors and defines the source term for accidental conditions.

Generation II and III reactor fuels in Europe take advantage of a large experimental feedback with a continuous evolution of fuel element design and materials, which allows maintaining high safety standards while adapting to the evolution of the operating conditions. Fuel performance codes, which enable the simulation of the behaviour of the fuel elements in reactor, are now an essential component of the design, licensing and safety assessment of nuclear fuels. The licensing of innovative fuel materials and design requires an extension of the current fuel performance codes to meet safety authority's requirements, in particular regarding the Verification, Validation and Uncertainties Quantification processes.

Opera HPC will work on four aspects to improve the approach and computational tools used by the nuclear research community and industry.

## 2.1 Basic research on the mechanical behaviour of fuel under irradiation

The objective is to obtain missing data, identify elementary mechanisms and develop physics-based models of the non-linear mechanical behaviour of fuel and fuel elements. This objective will be achieved mainly through the Work Packages 1 and 2 (see Figure 1) with a coupling experimental and modelling approach and the development of multi-scale mechanical model for fuel element. The research activity will address the questions associated to the creep and the rupture behaviours of irradiated $UO_2$ fuel to inform physically based modelling needed for advanced simulation.

## 2.2 Code development

This objective is devoted to the development and the qualification of open source 3D HPC simulation tools with parallel computing capabilities at the microstructure and fuel element scales, as well as a meshless prototype tool. This work has also the objective to provide interfaces and input data connecting these advanced tools with state of the art fuel performance codes as well as neutronic and thermo-hydraulic codes at core or assembly scales. The research activity for this objective is achieved in WPs 3,4 and 5 with respectively high fidelity input data and boundary conditions, open source code development and code qualification with verification, validation and uncertainties quantification.

## 2.3 Industrial application

The objectives of the project for the industrial application are: to improve the fuel modelling for industrial fuel performance codes, to demonstrate the benefits of 3D advanced simulation for fuel safety studies and to provide new safety assessments for enhanced accident tolerant fuels. The corresponding research activity will be done in the WPs 6 and 7 with respectively the development of improved industrial models and fuel safety studies with improved industrial fuel performance codes and advanced 3D simulation tools.

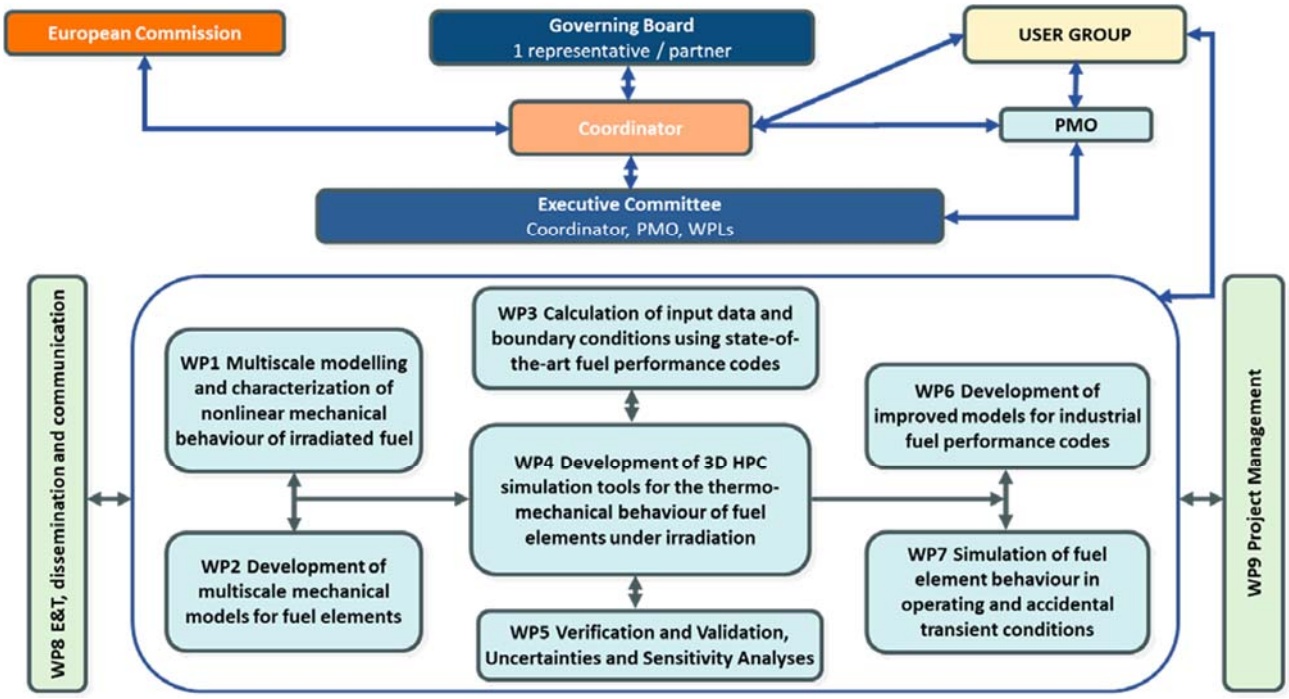


Figure 1: Project Structure

## 2.4 Education and training and dissemination of the project's results

The objectives are to transfer the methods, tools and results obtained in the project through open-access publications, workshops and exchanges with industrial end-users and training of a new generation of researchers.

# 3 OperaHPC dissemination plan

## 3.1 Communication and dissemination strategy

### 3.1.1 Objectives

The OperaHPC communication and dissemination objectives are:

- To promote the project's activities, objectives and the uptake of its results widely through targeted actions
- To engage in a two-way dialogue with the project's key customers
- To collaborate and disseminate the knowledge generated in OperaHPC to the project's community and stakeholders.

- To contribute to attracting the younger generation to the nuclear field
- To raise public awareness and contribute to the public acceptance of nuclear energy

### 3.1.2 Target audiences

The following audiences have been identified as the main target groups that OperaHPC will be addressing through its communication and dissemination activities.

- SNETP/NUGENIA community
- Fuel designer/manufacturers
- Utilities
- Reactor designers and operators
- Technical Safety Organisations
- International organisations such IAEA, OECD-NEA, GIF
- General scientific community
- European students
- General public

### 3.1.3 Key messages

An initial set of key messages for OperaHPC was developed to educate and inform the target audiences about the project, its objectives and expected outcomes and impacts. Additional tailored messages will be drafted to promote OperaHPC in the most effective way.

Based on the results and analyses carried out in the project, the messages below will be further refined and developed for each audience.

| TARGET AUDIENCE | MESSAGES | CHANNELS |
|---|---|---|
| NUGENIA community | The results generated in the OperaHPC project will significantly contribute to accelerate the Fuel Performance Code licensing for Gen2&3 reactor in a changing context with the energy mix and the use of enhanced accident tolerant fuels. | ▪ Website<br>▪ Newsletter<br>▪ Scientific publications<br>▪ EU channels<br>▪ Participation in and presentations at events / conferences / workshops<br>▪ SNETP channels (Website, newsletter) |
| Fuel manufacturers, utilities | The OperaHPC approach will help fuel manufacturers, operators and utilities to orient their activity with regards to innovative fuels. | ▪ User Group interactions<br>▪ Website<br>▪ Participation in and presentations at events / conferences / workshops |
| Reactor designers and operators | OperaHPC will provide reactor designers and operators with the necessary knowledge to demonstrate their understanding of fuel element behaviour and codes validation to safety authorities, in particular concerning its direct impact on safety. OperaHPC will provide improved fuel performance codes. | ▪ User Group interactions<br>▪ Website<br>▪ Newsletter<br>▪ Participation in and presentations at events / conferences / workshops |

| | | |
|---|---|---|
| TSOs | The OperaHPC results will bring the complementary knowledge to help license fuel performance codes. | ▪ User Group interactions<br>▪ Website<br>▪ Newsletter<br>▪ Participation in and presentations at events / conferences / workshops |
| International organisations such IAEA, OECD-NEA, GIF | The work carried out in OperaHPC will help/enable collaborations on code development with the open source approach. | ▪ Website<br>▪ Newsletter<br>▪ Participation in and presentations at events / conferences / workshops |
| General scientific community | OperaHPC will produce scientific and technical results for:<br>• multi-scale experiments and modelling of irradiated fuel mechanical behaviour<br>• Development of high Performance open source codes for the simulation of fuel thermo-mechanical behaviour<br>• VVQI for 3D simulation of fuel thermo-mechanical behaviour at microstructure and engineering scales<br>• Machine learning and reduced order modelling for fuel behaviour<br>• Fuel safety studies for enhanced accident tolerant fuel elements in normal and accidental conditions | ▪ Scientific publications<br>▪ Website<br>▪ Participation in and presentations at events / conferences / workshops<br>▪ Videos |
| European students | OperaHPC will contribute to training the next generation of researchers on fuel performance codes (multi-scale modelling, numerical simulation, high performance computing, safety studies,…) | ▪ PhD, Post-doc and mobility opportunities,<br>▪ Schools (training) , MOOC |
| General public | The work performed in OperaHPC will contribute to nuclear fuel design in order to maintain and even extend the production capacity of current nuclear reactors, while taking into account the evolving electricity mix and increasing requirements regarding the safety assessment of nuclear reactors. This will enable the electrification of the energy sector, which is a key step for the transition to climate-neutrality. | ▪ Website<br>▪ Exhibition to be displayed during open days and/or events aimed at the general public<br>▪ Videos |

Table 1: Main types of target audiences, message and channels of communication

### 3.1.4 Public website

The public part of the OperaHPC website was opened in November 2022. Then the collaboration space of this website was prepared and opened to the project participants in June 2023. It was designed and

developed to serve as an information and communication tool, as well as a platform for the project team. A snapshot of the home page is shown in Figure 2.

It acts as the main channel for news and updates with the aim to address the key questions that external visitors are expected to have, these include:

- What the project is about
- Who the partners of the project are
- What the project is delivering
- What the main advancements of the project are

It will be continuously updated and will evolve with the lifecycle of the project, according to the dissemination and communication policy of the project.

### 3.1.5 Newsletters

A total of 4 electronic newsletters will be distributed to the OperaHPC community to inform them on the latest achievements of the project, outputs and relevant events, conferences or workshops. Newsletters will be published on a yearly basis.

The results and statistics will be drawn for each newsletter. Conclusions and possible areas of improvement will also be indicated, with the aim to help optimise future mailings.

The first newsletter is planned for mid 2023.

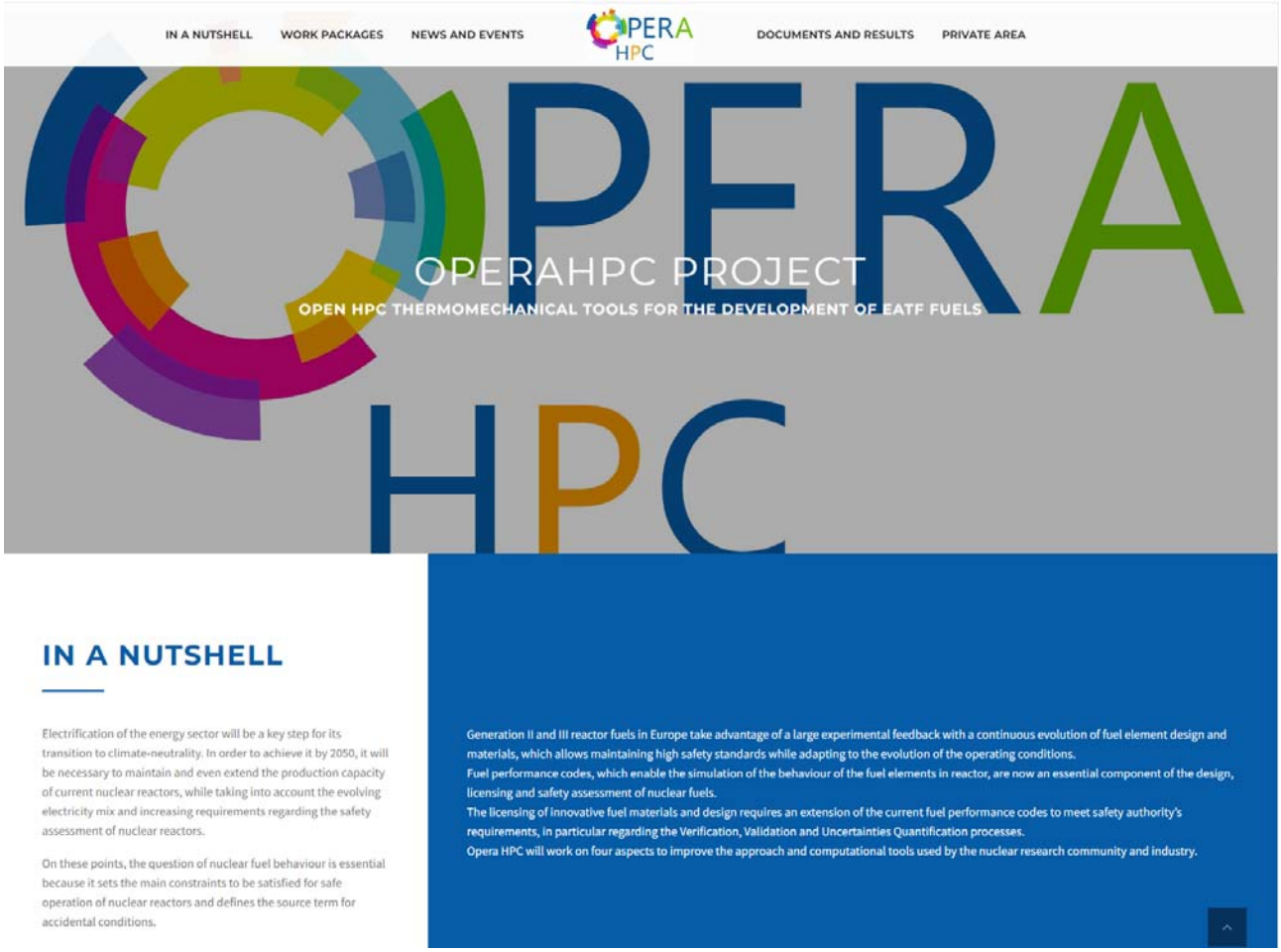


Figure 2: Screenshot of OperaHPC website

## 3.2 Dissemination plan

### 3.2.1 Scientific events

The project consortium will attend events that are relevant to the topic of the project and through which target groups can be reached. Information will be shared between the partners to ensure the project is properly represented at important events for the research community on nuclear materials and fuels.

The conference as follows were identified as major targets for the project.

- Meetings of the European Materials Research Society (E-MRS)
- EUROMAT conferences
- Fall meetings of the American Materials Research Society (MRS)
- NuMat – The Nuclear Materials Conference
- MMSNF – Materials Modelling and Simulation for Nuclear Fuels
- NuFuel workshop
- The TopFuel conference
- The ECCOMAS conferences
- The COSIRES conference
- The SNETP Forum

### 3.2.2 Scientific publications

A number of scientific publications in peer-reviewed journals will be prepared and submitted. The project will also follow the open access policy of Horizon Euratom by providing online access to scientific information that is free of charge to the end-user and that is reusable. In the context of this project, scientific information refers to peer-reviewed scientific research articles (published in scholarly journals), articles, conference papers and research data. As such, the project will combine different measures to foster open access to knowledge as much as possible.

Emphasis will be put on gold or green open access through the JPNM website. A specific budget has been reserved by several partners to cover the fees of gold open access publication.

The following journals have been identified as particularly relevant for the project.

- Journal of Nuclear Materials
- Physical Review B
- Journal of Physics: Condensed Matter
- Acta Materialia
- International journal of plasticity
- Journal of Open Source Software
- Nuclear materials and energy
- European Physical Journal Nuclear Science and Technology
- Nuclear Engineering and Design
- Nuclear Engineering and Technology
- Annals of Nuclear Energy

### 3.2.3 Training

The Education and Training Activities planned in OperaHPC, in particular the co-organisation of 2 summer schools and 2 workshops, will also contribute to the dissemination of the results of the project. They will also encourage the younger generation to follow their careers in the nuclear field.

### 3.2.4 European dissemination channels

The official channels set up by the EU institutions will be used if relevant to disseminate the project's results. The following official EU dissemination channels will be targeted:

| | | |
|---|---|---|
| Magazines | Research*eu results magazine | https://cordis.europa.eu/research-eu |
| | Horizon – The EU Research and Innovation Magazine | https://horizon-magazine.eu/ |
| Portals | CORDIS | https://cordis.europa.eu |
| | Horizon 2020 newsroom | www.ec.europa.eu/programmes/horizon2020/en/newsroom |

Table 2: EU dissemination channels to be used in OperaHPC

### 3.2.5 Outreach activities

The partners in the project will initiate or participate in outreach activities that cover the general scope of OperaHPC:

- Nuclear materials
- Fuel Performance codes
- High Performance computing and Open source
- Reduced order modelling, machine learning, …

The communication units of several partners of OperaHPC will be involved in preparing these activities. Collaboration and dedicated events will be sought with EERA, JPNM, ESNII and with related Horizon Europe projects.

Exhibition material will be produced to be displayed at events that attract the general public, such as open days at the consortium partners' sites. The content will have an educational approach and describe in a simple and easy to understand language the issues pertaining to nuclear materials, fuel performance codes, safety studies and innovation for fuel development. The exhibition will take the form of posters that will be easily transportable. This will contribute to changing the public perception of the expertise associated to the development of nuclear fuels.

Then, short videos will be if possible produced by the project and be posted on public institute websites and social media, and demonstrations and posters will be presented at science fairs.

The main events targeted are

- JRC Open Day
- CEA Cadarache Open Day
- European Researchers' Night
- Open days or science fairs of universities

### 3.2.6 Overview

Table 3 synthesises the communication and dissemination actions of OperaHPC and the key performance indicators (KPI) that will be used to monitor the progress of these activities.

| CHANNELS & ACTIONS | AUDIENCES | KPIs |
|---|---|---|
| OperaHPC website | Scientific and technical audiences, students, general public | ▪ Number of page views<br>▪ Average time on page |
| Newsletters | Scientific and technical audiences | ▪ Number of subscribers |
| Media/other websites/channels | Scientific and technical audiences, students, general public | ▪ Number of articles published/mentions about OperaHPC |
| Outreach activities | General public | ▪ Number of attendees<br>▪ Number of events where the exhibition was displayed |
| Events | Scientific and technical audiences | ▪ Number of conferences where OperaHPC results were presented |
| Publications | Scientific and technical audiences | ▪ Number of articles published about OperaHPC<br>▪ Number of mentions |
| Training | European students | ▪ Number of participants to the training activities |
| EU channels | Scientific and technical audiences, general public | ▪ Number of mentions<br>▪ Number of articles published about OperaHPC |

Table 3: Synthesis of the communication and dissemination actions of OperaHPC and corresponding key performance indicators

# 4 Exploitation activities of the project results

This section gives an overview on the project exploitation activities of the project outcomes during the project and beyond the project's duration.

## 4.1 Objectives

The aim of the exploitation activities of OperaHPC is to promote the utilisation of results of the project:

- in further research activities
- in developing, creating and marketing products or processes
- in creating and providing services
- in standardization activities.

This utilisation can be done by the project partners or by others via licenses given by the owners of the data generated.

## 4.2 Exploitable results produced in OperaHPC

OperaHPC will produce various types of exploitable results:

- Data, results, knowledge
- Experimental setups
- Computational and analysis methods
- Codes
- Education and training material
- Communication materials

## 4.3 Exploitation measures

### 4.3.1 R&D and academic exploitation

The results obtained during the project will enable the academic and nuclear research organizations involved in OperaHPC to make better proposals in the field of modelling and simulation of nuclear fuel elements. These results will be composed of: knowledge and material data, open source fuel performance codes, methodologies and tools for the improvement of industrial fuel performance codes, improved fuel models, for the description of fuel element thermomechanical behavior, and associated safety studies with eATF assessments.

First, the close contact with industrials in the project and in the user group will enable them to increase the number of research contracts with industry. Finally, the High Performance Computing open source codes developed in the project are expected to become a European standard for the sharing and the capitalization of tools devoted to the simulation of fuel element behavior in the reactor. The open access of main technical results is of course a key aspect of this change of research approach.

### 4.3.2 Industrial use

The industrial partner involved in OperaHPC expects to use the results obtained and the codes developed to improve their operations. This will enable them to create new business opportunities.

OperaHPC will interact with the industrial actors in charge of the development and licencing of innovative fuels for current European reactors, but also with manufacturers and utilities. An end-user group involving the representatives has been constituted. Table 4 lists the organizations that have already given OperaHPC their full support, as well as their representatives. More organizations are expected to join the group.

| Organisation | | Representative | Position |
|---|---|---|---|
| EDF | France | Antoine Ambard | Research engineer |
| EK-CER | Hungary | Zoltan Hozer | Head of Fuel and Reactor Materials Department and chair of OECD/NEA WGFS |
| Framatome GmbH | Germany | Wolfgang Schmid | Material designer |
| TVO | Finland | Arttu Knuutila | Team leader, fuel procurement |
| Vattenfall | Sweden | Pal Efsing | Senior Specialist in Fracture and Materials Mechanics and professor at KTH |
| Westinghouse | Sweden | Paul Blair | Principal engineer for fuel rod design methods and methodology |

Table 4: User group members

Two plenary meetings will be organised between OperaHPC participants and the EUG, at the beginning and at the end of the project, and regular information exchanges will take place between these two meetings. The open access policy will ensure open debate with and within this group. The EUG will have a key role in OperaHPC, as it provides its path enabling its innovative approach towards fuel qualification to be put in action.

In addition, the final OperaHPC workshop at the end of the project will be dedicated to showing and sharing the results obtained to and with end-users. The user group will be invited and effort will be made to attract as many industry representatives as possible, both European but also from outside Europe.

### 4.3.3 Support to policy makers

Most nuclear research organisations involved in OperaHPC play a role of technical support to their respective governments concerning nuclear energy issues and policies. The project's results will enable them to improve the quality of their technical answers to questions of their authorities.

In addition, OperaHPC project has been proposed under the auspices of the SNETP organization [1] with a label given by the NUGENIA pillar. The OperaHPC approach and objectives are part of the Technical Area 7 [2] activity, as reported in the NUGENIA global vision document [3]. On a larger scale this research activity is in line with the strategic research agenda of the JPNM [4], as well as the nuclear materials program for all reactor generations developed in the ORIENT-NM project [5].

### 4.3.4 Civil society

Training and communication materials can be reused to inform the scientific community and the general public on nuclear energy and nuclear fuels, as well as on the role simulation can play in improving the safety and sustainability of nuclear energy.

# 5 Conclusion

The exploitation and dissemination plan of the OperaHPC project is described in this document. The OperaHPC project offers a large panel of objectives from basic research up to industrial safety studies trough open source code development. Consequently, the dissemination and exploitation plan has been defined to be in line with all type of expected results.

# 6 References


1 https://snetp.eu/

2 Technical Area 7 "Fuel Development, Fuel behaviour in the reactor and Spent Fuel Management" in the NUGENIA pillar of the SNETP organization

3 NUGENIA Global Vision https://snetp.eu/wp-content/uploads/2021/06/NUGENIA-Vision-June-2021.pdf

4 http://www.eera-jpnm.eu/filesharer/documents/Materials%20for%20Sustainable%20NuclearEnergy%20-%20SRA%20of%20the%20EERA-JPNM%20-%20web%20version.pdf

5 L. Malerba et al., Materials for Sustainable Nuclear Energy: A European Strategic Research and Innovation Agenda for All Reactor Generations, Energies, 15, 1845 (2022) https://doi.org/10.3390/en15051845