



ORIENT- NM

Organisation of the European Research Community on Nuclear Materials

A Coordination and Support Action in Preparation of a Co-Funded European Partnership on Nuclear Materials



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Demonstration of the added value of a EJP on nuclear materials

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List of abbreviations

CEP	Co-funded European Partnership
EERA-JPNM	Joint Programme on Nuclear Materials of the European Energy Research Alliance
EC	European Commission
EJP	European Joint Programme
EU	European Union
Gen II	Second Generation of nuclear reactors
Gen III	Third Generation of nuclear reactors
GenIV	Fourth Generation of nuclear Reactors
MS	Member State
NE	Nuclear Energy
NECP	National Energy and Climate Plans
NM	Nuclear Materials
LTO	Long Term Operation
ORIENT-NM	Organisation of the European Research Community on Nuclear Materials
POQ	Programme Owners Questionnaire
R&D	Research and Development
SNETP	Sustainable Nuclear Energy Technology Platform
SRA	Strategic Research Agenda
WS	Workshop
WP	Work package

Summary

The ORIENT-NM is a 30 months Euratom-funded Coordination and Support Action (CSA) started in October 2020. It has been structured around six Work Packages (WPs) developed across different activity lines having the common objective to explore the possibility of establishing a Co-Funded European Partnership (CEP) on nuclear materials, by designing a complete plan for such CEP considering all its aspects. To this end, the ORIENT-NM was aimed to exploring consensus on a European partnership on nuclear materials, establishing the relevant Strategic Research Agenda (SRA), governing structure and means for interaction with stakeholders, based on the SRA of SNETP and EERA-JPNM.

This document is part of WP1 activities of which the last milestone is to demonstrate the added value of a CEP on NM based on the outcomes of the overall project activities and mainly on those arising from the close interaction undertaken with European Commission (EC), stakeholders, and Member States (MS).

ORIENT-NM philosophy overview

ORIENT-NM is a Euratom-funded Coordination and Support Action (CSA) to explore the consensus on a co-funded European partnership on nuclear materials (CEP-NM), based on a well-structured governance and on an effective management of funds, in agreement with the NM-R&D needs across Europe.

The main milestones of the project involved the development of a Vision Paper and a Strategic Research Agenda (SRA) for structural and fuel materials for all nuclear fission reactor generations until 2040, and a close interaction with MS, European Commission (EC) representatives, and other stakeholders, to meet requirements, and raise interest by demonstrating the value of a CEP-NM.

The ORIENT-NM analysis of the national energy and climate plans (NECP) suggests that, from now to 2040, nuclear power will be maintained or even expanded in Europe via long-term operation (LTO), power upgrades, and new LWR builds. Concerning next generation (i.e., Gen-IV) systems, there are overall not yet ready to be marketed, due to the targeted high temperatures that, combined with very high neutron dose in core components (because of the high burnup) and with the use of non-aqueous coolants, trigger severe degradation processes for materials and components¹.

In this framework, also because of the challenges posed by the clean energy transition, the research on NM must be strengthened to accelerate the design, manufacturing, and qualification of innovative nuclear materials to reduce their time to market. This is the main reason to implement an integrated European nuclear materials research programme, which could be instrumental to make a coordinated use of assets that are currently scattered across member states and associated countries, as well as to coordinate assets, leverage national and industrial support, and give continuity to specific research lines, including non-nuclear materials.

The CEP-NM envisaged by ORIENT-NM SRA will pivot around five research lines transversal to all classes of nuclear materials and having significant impact on the safety and efficiency of current and future NPPs (well described in the deliverable D2.4¹). These materials stemmed from the analysis of the European MS energy plans and of the short and long-term needs of the nuclear industry and have been selected in order to implement a cross-cutting approach addressed toward the needs of all different national strategies on nuclear energy.

¹ <http://www.eera-jpnm.eu/orient-nm/?q=jpnm&sq=sub2>

The fifteen years horizon of the CEP-NM activities are aimed at the creation of sufficiently strong foundations, in terms of flexibility and extendibility of the developed methodologies, to enable the application of the approaches pursued within each research line for the benefit of the nuclear energy world, addressing the most important (in that future moment) requirements of nuclear (and also non-nuclear) systems, trying to move in the direction of being also economically self-sustainable, at least for some of the activities.

To accomplish the ORIENT-NM objectives, MS representatives have been engaged in a two-way dialogue to collect information on national programmes, define contents and priorities, analyse MS interest for a future CEP-NM, and provide information such as socio-economic benefits, financial aspects, structure, and the possible implementation strategy of an effective SRA. To this end, two workshops (summarised in deliverables D5.5² and D5.7²) have been held within the project to discuss the progress made in each ORIENT-NM work package and to receive input for the development of key deliverables. As a complement to the workshops, further information was collected through the Programme Owners Questionnaire (POQ) (whose results are reported in the Annex1 of deliverable D1.4¹). Thus, information concerning the MS requirements and their expectations about a CEP-NM, has been gathered.

The questionnaire results have given an overview of the number and type of entities directly and indirectly involved in the definition of contents and priorities of both the national NE-R&D and NM-R&D and providing and managing the related funds across Europe. The main actors are ministries (mainly those in charge of activities related to Economy, Energy, Research and Environment), research centres, institutes, agencies and industrial companies, universities and regulatory bodies. In some cases, one or more of these actors are also involved in the definition and coordination of the National NE- and NM-R&D programme when one or both exist.

Due to the variety of entities involved, close interaction with all possible stakeholders was mandatory to develop a SRA that is able to implement and unify the different policies, plans, ideas, and attitudes towards nuclear energy, of the involved countries.

² <http://www.eera-jpnm.eu/orient-nm/?q=jpnm&sq=sub5>

The added value of a future Co-funded European partnership on Nuclear Materials

The added value of a future CEP-NM has to be identified in the advances and long term benefits which can be achieved in the field of nuclear materials to improve the performance of the current generation of nuclear reactors, as well as to make resilient and sustainable the next one. This value is clearly summarized in the following crucial points, revealing why a future CEP-NM, as envisaged in the ORIENT-NM project, could be instrumental in strengthening the European leadership in NM and energy technologies in general.

1. **The CEP-NM shall coordinate** both Euratom and national-relevant activities on nuclear materials under the same umbrella, providing a stronger coordination of NM R&D projects's, and a stronger harmonisation of the efforts and their deployment;
2. **The CEP-NM shall allow the optimisation** of the use of national competences, facilities, and of the present and future infrastructures, by centralising the funds allocated to the R&D projects;
3. **The CEP-NM shall strengthen R&D activities** on materials, by avoiding fragmentations and duplications, and by filling gaps within specific key subjects;
4. **The CEP-NM shall accelerate the development** of advanced or new materials solutions, including manufacturing processes and their qualification for use in harsh environments for nuclear and non-nuclear materials;
5. **The CEP-NM shall trigger a dialogue** between fusion, fission and energy communities, catalysing a cross-fertilisation of the related research areas;
6. **The CEP-NM shall strengthen its implementation** by involving industries as active partners and targeted end-users, and encouraging their financial support;
7. **The CEP-NM shall provide continuity** to the EU R&D programme on NM over a long-term horizon;
8. **The CEP-NM shall create a synergy** between the European Commission and the participating countries, allowing the co-funding of the participating countries via in-kind work and investments;
9. **The CEP-NM shall provide higher flexibility** on the Research Program on NM, capable of following the demands and needs of industries.
10. **The CEP-NM shall trigger new cooperations** among academia, research organisations and industrial partners all over Europe.

The above points have been fully explored and explained through all the deliverables produced during the 30 months of ORIENT-NM activities. Of these, the final version of the Vision paper published in October 2022 and the final version of the SRA, to be published in May 2023, are key to get the overall picture of the ambitious milestones the CEP will be able to achieve and the pathways that will allow their implementation.

The following section provides a synthetic overview of these two documents. It is worth noting that all the results and the expected benefits that will arise from the CEP-NM will be driven by the concept of "cooperation", which represents the pillar on which the added value of a European Partnership on nuclear materials will be founded.

ORIENT-NM Vision

The ORIENT-NM Vision Paper¹ describes the importance of nuclear energy in the transition energy process in Europe, presents the crucial role of materials in nuclear energy development, and indicates the way to address the materials needs for the development of nuclear systems, including fusion. It represents the vision of the European research community on nuclear materials, formed by the alliance between the Sustainable Nuclear Energy Technology Platform (SNETP)³ and the Joint Programme on Nuclear Materials of the European Energy Research Alliances (EERA-JPNM)⁴ regarding: Sustainability, Innovation and Targeted Collaboration. These three concepts are the foundation on which the ORIENT-NM vision envisages the application of modern materials science approaches, to accelerate materials development and qualification pace.

Very different nuclear systems are used or considered for the future in the various EU member states and associated countries: five different systems of Gen II/III, and 6-8 different systems of GenIV and Cogeneration, each with various designs. In this framework, to address the challenges related to the materials needs and, therefore, the challenges posed by the clean energy transition, five materials science practices and as many relevant research lines define the pathways to be pursued within the next decade towards ambition Grand Goals of relevance. These Research Lines are consistent with the activities foreseen in the Strategic Energy Technology Plan (SET-Plan) on nuclear safety and with the Advanced Materials 2030 Manifesto, and are transversal to all materials classes and varieties, irrespective of the specific nuclear generation

³ <https://snetp.eu/>.

⁴ <http://www.eera-jpnm.eu>

application, namely: Nuclear materials' test-beds, Nuclear materials acceleration platforms (nuclear MAPs), Advanced predictive methodologies, Improved material and component health monitoring, and European nuclear materials' FAIR database.

These goals are thought to serve equally well different national nuclear energy strategies and policies aimed at improving industrial competitiveness. Thus, they can be shared between all involved member states and associated countries, allowing their needs to be met by valorising their research and industrial assets.

In this framework, the European partnership is the tool to enable the integration and coordination of a single nuclear materials research programme built around the shared Grand Goals, by optimising the use of national competences, facilities and (present and future) infrastructures to strengthen European leadership. It will guarantee continuity along the established research lines, overcoming the current model based on separated and independent projects. This objective can only be achieved by promoting close, structured and continued collaboration between academia, research organisations and industrial partners all over Europe.

ORIENT-NM Research Strategic Agenda

For the effective implementation of the five research lines, the ORIENT-NM SRA is directed towards the exploitation of actions that will be carried out in close collaboration with existing initiatives in the materials area or in the nuclear field, namely:

- accelerate materials qualification and industrial upscaling through the coordinated exploitation of existing and future facilities and infrastructures at the service of both industry and research;
- develop Materials Acceleration Platforms (MAPs) dedicated to nuclear materials, or more generally materials for harsh operating conditions, to apply a "design and control" paradigm for materials screening and perhaps discovery;
- develop blended models combining "traditional" multiscale tools and approaches with recent data-driven empirical trends.
- establish intelligent materials health monitoring systems, extended to materials properties over the whole component lifecycle using machine learning algorithms;
- create (if needed) and crucially populate with data FAIR nuclear materials databases, which should provide a modern, user-friendly, flexible, efficient, protected and especially attractive framework to store, cure, analyse and exploit data, coupled with the consensual definition of materials examination protocols and

relevant data format, as a crucial prerequisite for the success of the above endeavours.

To this end, the five research lines will be transversal to seven specific classes of materials, as shown in Figure 1.

	Concrete	Metallic alloys for structural components	Refractory materials for structural components	Polymers for cables and structural applications	Fuel cladding materials	Nuclear fuel materials (fissile and fertile)	Materials for neutron control: absorbers, moderators, reflectors
Safety	External containment, last barrier to release of radioactive material, protection of reactor core from external agents	Vessel: main barrier to release of radioactive material	Maintain integrity at high temperature in both operating or accidental conditions	Efficient transmission of energy or signals	Barrier to radioactive material release into coolant	Inherent barrier to fission product release Heat production even after shutdown	Control of reaction
Efficiency		Piping and supports define inlet/outlet temperature	Higher temperature brings higher efficiency		Define possibility of high burnup	There is no reactor without fuel! Defines neutron spectrum, burnup, etc.	Define neutron spectrum and criticality

Figure 1. Classes of materials constituting nuclear reactors and roles in safety and efficiency of operation

The issues to be addressed for each of the materials classes that appear in Figure 1, specifically for metallic alloys for structural components, fuel cladding materials, nuclear fuel materials, and concrete, were identified by the technical advisory group (TAG) of the ORIENT-NM project, and summarized in the materials identity cards (deliverable D2.1¹). The information reported in each card represents the past, and ideally the future of each material in terms of R&D efforts, addressed to the improvement, exploitation, and marketing.

The activities foreseen by the SRA are aimed to cover all the classes of the proposed NM and to accomplish the expected results from the five research lines activities within a horizon of fifteen years from the starting date.

Initially, during the first five years, the CEP activities will be mainly addressed to the fission applications of both structural materials (metallic and concrete) and fuel element materials (fuel and fuel cladding), including identification of needs and preparatory study for neutron irradiation. The main focus will be put on innovation for the benefit of each reactor generation by selecting simple, but varied, case studies in each research line. Finally, strategic activities will be carried out on the three other classes of materials

(polymers, refractory structural materials and neutron control materials) to (re)build the corresponding European research communities.

For the fifteen years horizon, CEP activities will encompass all seven classes of NMs also, including fission-fusion cross-cutting issues.

In the deliverable D2.1 all the expected results are reported and well explained, giving the exact picture of the strong impact that the CEP-NM will have in the NM field. Indeed, the planned approach, from the implementation of each specific research activity to the governance and structure design, will allow the creation of strong foundations upon which to build a new-concept R&D programme on nuclear and non-nuclear systems, which will be able to look to the future by learning from the past.

Conclusions

The consolidation of the nuclear materials domain in Europe was triggered by different actions, such as the creation of the Strategic Energy Technology (SET) plan, the joint programmes promoted by the European Energy Research Alliance (EERA), including the EERA Joint Programme on Nuclear Materials, the SNETP-NUGENIA, and the Jules Horowitz Material Test Reactor.

Thank to a close and transparent interaction process, ORIENT-NM was instrumental in the discussion with stakeholders and MS regarding the launch of a CEP in nuclear materials and fuels.

The CEP is now included in the Euratom programme 2023-2025, that has been published in March 2023. The deadline for the proposal submissions is expected to be in November 2023 and the GA to be signed in summer 2024.

The ORIENT-NM work carried out on the partnership structure and governance encompassed all possible aspects in advance of the proposal, i.e., legal issues, resourcing, implementation and quality management, data and knowledge management, and education and training. By mapping the differences in structures and executions of existing partnerships, it has been concluded that the nuclear material partnership would be the co-funded type, which is probably the easiest to build and manage.

The co-funded rate of 55% for the CEP implementation could make it unattractive from the economic point of view for stakeholders and mainly industry. Nevertheless, the basic concepts making the CEP a tool to implement the European R&D programme on NM

through a new and more effective approach should also drive the initial perception towards the real advantages of this proposal. Indeed, the co-funded rate of 55% can be considered an incentive for the participants to implement all the envisaged activities and, therefore, to be more engaged, allowing the success of the initiative and its continuity. Moreover, the analysis of several scenarios for the use of resources shows a notable benefit of the CEP concept, with a reduction of the costs of management, E&T, and dissemination, and a more efficient use of resources, centralising the management of various projects.

The CEP-NM is implemented through a well defined structure, a means of governance with clear legal parameters and rules of procedure (RoP), i.e., specifications built on the principles laid out in the Consortium Agreement (CA), which has been tuned to better fit the need of the CEP. This includes legal solutions to face the different issues, characterising the different partners' policy, and adequate governance structure.

The Quality Assurance criteria will be the umbrella under which all the works, processes, initiatives and management of the CEP actions will be implemented.

To address the urgent need which the energy transition requires, as well as the challenges posed by emerging energy technologies, a European coalition of workforce, skills and funds in the nuclear materials field could represent the strong point of the path toward final sustainable energy solutions. In this way, a future CEP-NM, as envisaged in the ORIENT-NM project, will represent an added value for the entire European community.



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