

The VERONICA (Versatile European Reactor for Neutron Irradiation and Nuclear Research) Project Update: Stakeholders, Utilization and Preliminary design

A. Pungerčič^{1,2}, B. Levpušček^{1,2}, J. Malec^{1,2}, K. Ambrožič^{1,2}, V. Radulović^{1,2}, I. Tiselj^{1,2}, N. Thiollay³, G. Bignan³, C. Destouches³, R. Jacqmin³, X. Wohleber³, A. Lyoussi³, J. F. Villard³ and L. Snoj^{1,2}

¹ “Jožef Stefan” Institute, Jamova cesta 39, 1000 Ljubljana, Slovenia

²Faculty of Mathematics and Physics, University of Ljubljana Jadranska ulica 19, 1000 Ljubljana, Slovenia

³CEA, DES, IRESNE, Cadarache F-13108 Saint-Paul-Lez-Durance, France

luka.snoj@ijs.si

ABSTRACT

Research reactors (RRs) are vital for advancing nuclear technologies, supporting medical isotope production, materials research, neutron science, and education. Europe faces a growing challenge due to its ageing RR fleet and declining reactor numbers. To address this, the VERONICA (Versatile European Reactor for Neutron Irradiation and Nuclear research) project proposes a new flexible research reactor in Slovenia, aligned with strategic, climate and nuclear EU goals. The reactor concept includes a dual-core design: a Zero-Power Reactor (ZPR) and a 5 MW Multi-Purpose RR (MPRR), enabling advanced multiphysics research and material testing through spectrum-shifting capabilities. This paper outlines the initial strategic development phase led by JSI and CEA, including stakeholder analysis, identification of technical requirements, and preliminary design considerations. The stakeholder-utilisation analysis is presented for both the MPRR and ZPR concept, showing that reactors are complementary and a benefit of co-locating in a single facility. The aim of the paper is to present the VERONICA project and invite participation from prospective users and collaborators across Europe.

1 INTRODUCTION

Nuclear research reactors (RR) are essential facilities for nuclear research, needed for the development of nuclear technologies, both fission and fusion, medical isotope production, material and environmental science, neutron sources, training and education, and commercial reactor development and operation. The broad and diverse fleet of RRs in Europe is ageing (average RR age of 59 years) and their number is decreasing (from 300 to 31 operational RRs), due to the recent shutdown of several low- and medium-power reactors. Furthermore, in comparison to the world average, presented in Figure 1, the difference in median age of RR's is 10 years, indicating a high number of older RR's in Europe. This challenge was thoroughly addressed in the scope of the H2020 project TOURR (Towards Optimized Use of Research Reactors) in which the main recommendation for the long-term EU-RR strategy is to build in addition to current RR projects (at least) two RR, a medium-flux multipurpose and a flexible zero-power reactor, accessible to all EU member states [1].

Analysed parameter	Europe	World
Operational RR	31	197
Average age [years]	59	51
Median age [years]	65	54

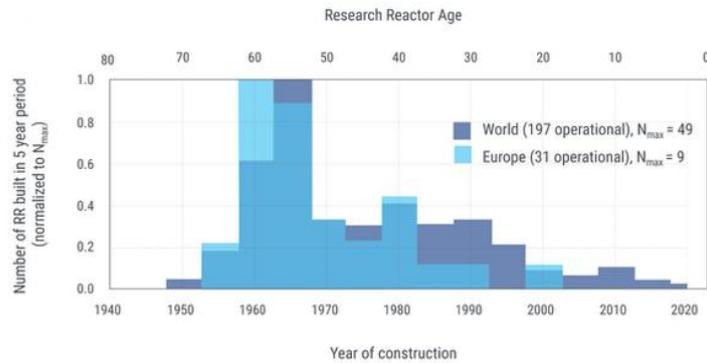


Figure 1: Current status of the EU RR fleet (left) and their age profile, compare to world average (right)

In addition to the decrease of RRs in Europe, a new research reactor is in line with EU's vision across multiple directives: addressing the decarbonization of society (reinforcing the Green Deal [2]), industrial competitiveness (in line with Draghi Report [3] and EU Competitiveness Compass [4]), energy and material autonomy (aligning with Self-Reliance, Defence and REPowerEU strategies [5,6,7]), nuclear and Small Modular Reactor (SMR) strategy (8th Nuclear Illustrative Programme [8]), and falls within the Important Projects of Common European Interest (IPCEI) [9]. Europe's ambitions goals and targets will need substantial research and development (R&D), as well as education and training (E&T), for which the necessary infrastructure is needed that enables experimentation, testing, validation, and human capacity building. Without new infrastructure – especially flexible, user-oriented research reactors none of the high-level EU goals can be realized.

The VERONICA project, addresses the challenges of ageing RR fleet and the need for new nuclear infrastructure by proposing a new versatile European research reactor in Slovenia [Malec J.]. VERONICA is designed not to compete with, but to complement, Europe's existing and emerging highly specialized research facilities, such as the high-flux material and fuel test Jules-Horowitz Reactor (JHR) [10], fusion relevant material testing facility IFMIF – DONES [11], medical isotope and material test reactor PALLAS [12], neutron science facility the European Spallation Source (ESS) [13], and accelerator driven system MYRRHA [14].

The first step on the path of commissioning a new research reactor, is the preparation of a comprehensive strategy and scientific foundations for the decision-makers. A joint project between Jožef Stefan Institute (JSI) and Commissariat à l'énergie atomique et aux énergies alternatives (CEA) was launched in 2025 with the main goal of preparing all the needed documents for the decision-makers. The initial tasks for the development of the implementation strategy that the decision-makers can make use of, are presented in this paper. The main purpose of this paper is to present the VERONICA project and attract interested and potential users to participate in it.

The first part of the paper presents the current status of the VERONICA RR project, its phases and current timings. The second part involves the review of the stakeholder needs and the identification of potential stakeholders. Complementary utilization of the VERONICA research reactor is presented by the identification of RR activities. A stakeholder-utilization matrix is presented for both a Zero-Power Reactor (ZPR) and a Multi-Purpose RR (MPRR). The last part of the paper addresses the reactor design, its requirements and the feasibility of a dual-core facility, operating both a ZPR and MPRR reactors.

2 THE VERONICA PROJECT

The VERONICA project (logo presented in Figure 2) is a strategic initiative to develop a roadmap for a new European research reactor in Slovenia, addressing the decline of research reactors, increasing demand for nuclear research services, and supporting Europe's transition to a zero-carbon society.

The project's main objective is to produce a comprehensive strategic plan and implementation roadmap. It can be structured into four main tasks. Firstly, it will assess the stakeholders and their needs by surveying existing European research reactor initiatives and identifying relevant user groups and their functional requirements. Section 3 of this paper presents the identified stakeholder groups and their utilizations in detail. The second task of the project aims to define the technical and functional requirements by evaluating current and emerging reactor designs and exploring diverse application areas. The objective of the third task is the selection and refinement of the two complementary reactor concepts—a Zero-Power Reactor (ZPR) and a Multi-Purpose Research Reactor (MPRR)—with the potential for co-location. The final task includes conducting a comprehensive feasibility study, developing a sustainable and market-aligned business model, and formulating a strategic plan to guide implementation. More information regarding the project can be obtained on the official website: <https://veronica.ijs.si>.



Figure 2: VERONICA project logo. The official website: <https://veronica.ijs.si>.

The possibility of a new research reactor in Slovenia was first considered in 2019 [15], due to the further increase of utilization of the current JSI TRIGA Mark II research reactor [16]. Subsequently, a paper presented at NENE 2022 [17] elaborated on planning aspects and identified suitable reactor technologies for the proposed facility. This paper also outlined recommended milestones from the "Feasibility Study for New Research Reactor Programmes" by IAEA, presented in Figure 3 [18]. According to the IAEA timeline, ongoing activities within the VERONICA project align with phase 1.

The initiative for a new research reactor has gained significant momentum through acknowledgment in major national strategic documents, including Slovenia's National Climate and Energy Plan [19], the Resolution on the Long-Term Peaceful use of Nuclear Energy in Slovenia [20] and Research Infrastructure Development Plan 2030 [21]. The inclusion of the reactor project in these documents underscores the national recognition of the necessity for this infrastructure and signals readiness to proceed toward subsequent construction phases.

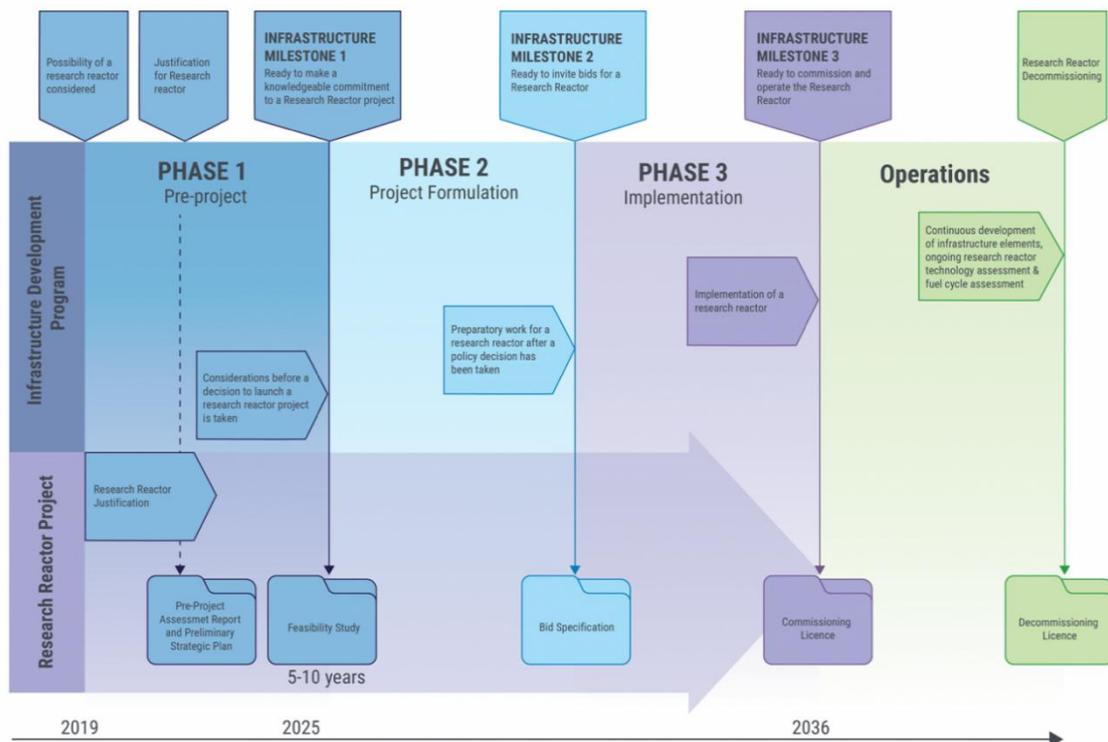


Figure 3: Recommended milestones adapted from "Feasibility Study for New Research Reactor Programmes" by IAEA [18].

3 UTILISATION AND STAKEHOLDERS

Drawing on the technical and strategic knowledge of project partners—including Jožef Stefan Institute (JSI), Commissariat à l'énergie atomique et aux énergies alternatives (CEA) we identified 30 stakeholders across different sectors such as:

- Government and regulatory bodies
- International research collaborations and networks
- Universities
- Research Institutions
- Healthcare and medical research institutions
- Industry and private sector

The utilization was determined by analysing research reactor applications, both for ZPR and MPRR. The most complete list of RR applications was available from the TOURR project [1]. For the analysis, a grouping of the applications was used to select most important general utilization sectors:

- Public outreach, education & training
- Instrumentation & method development / calibration
- Support for reactor design, safety & code validation
- Nuclear data & benchmark experiments
- Specialized industrial & medical applications
- Isotope production & neutron source
- Radiochemistry & radiation chemistry

- Material testing & radiation effects
- Neutron beam applications

To connect the stakeholders to applications and analyse how an MPRR and ZPR can be complementary in a single facility, we developed a Stakeholder–Utilisation Matrix, mapping stakeholder categories to specific experimental and training capabilities. The matrix serves as a guiding framework for prioritizing reactor functionalities and infrastructure during the design phase, while also providing a transparent roadmap for stakeholder engagement and service development. The MPRR and ZPR stakeholder-utilisation matrices are presented in Figures 4 and 5, respectively.

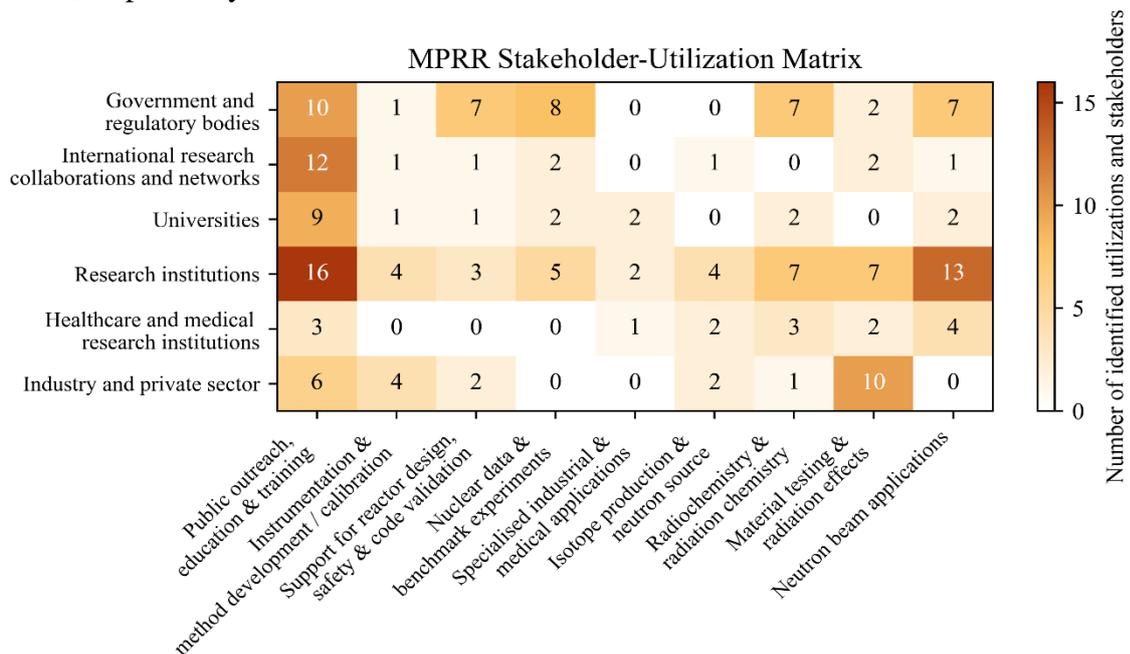


Figure 4: Stakeholder-utilization matrix for MPRR, co-located in the VERONICA facility.

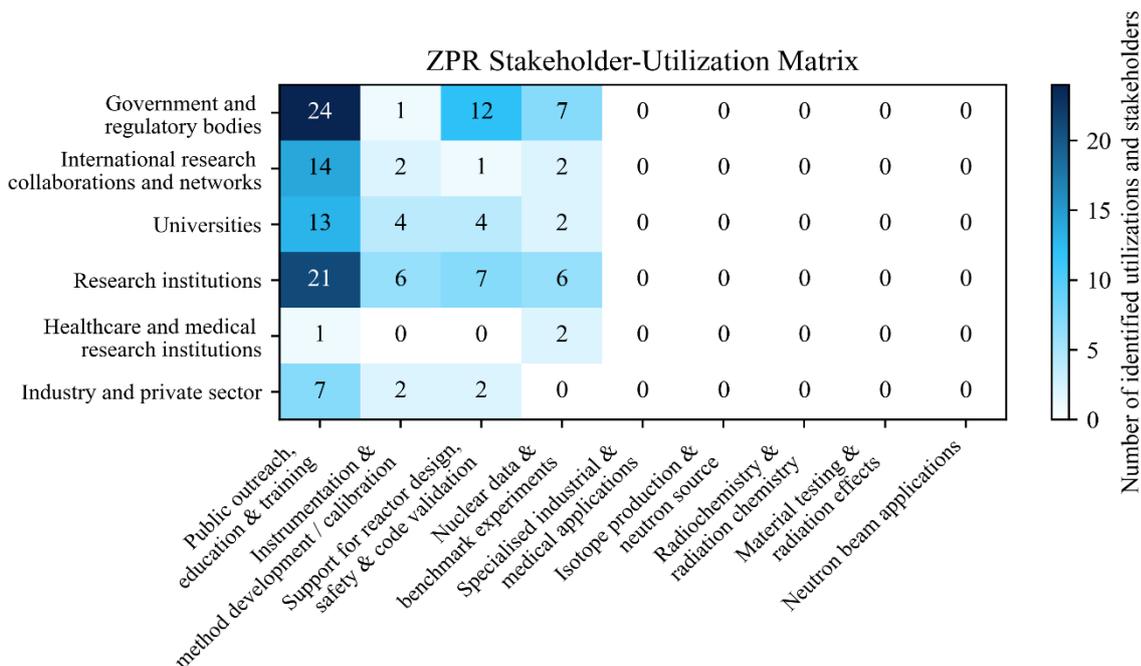


Figure 5: Stakeholder-utilization matrix for ZPR, co-located in the VERONICA facility.

Based on this analysis, we defined the most valuable applications for each reactor:

- For the MPRR: material irradiation, fuel qualification, radioisotope production, thermal-hydraulic-neutronic coupled experiments, neutron beam applications, radiochemistry & radiation chemistry.
- For the ZPR: education & training, public outreach, support for reactor design, safety analyses & code validation, benchmark experiments via reactivity measurements (e.g., oscillation method), nuclear data determination, method developments.

4 PRELIMINARY REACTOR DESIGN

The preliminary design of the VERONICA facility supports a wide range of experimental and application driven use cases—not only those currently well established in existing research reactors, but also those that may emerge in the future. This introduces an inherent level of uncertainty, as it is difficult to anticipate the specific requirements of future applications. To address this challenge, the design philosophy of the reactor is focused on flexibility, modularity and accessibility. The preliminary design includes a compact up to 5 MW pool-type multi-purpose research reactor (MPRR), complemented by a co-located Zero Power Reactor (ZPR). Such co-location strategy is similar to ISIS + OSIRIS Research Reactors at CEA, Saclay [22,23], allowing the ZPR and the MPRR to share support infrastructure while serving distinct application roles.

4.1 Functional and technical requirements

It should be noted that the presented functional and technical parameters are not final and are subject to change in the future. Based on preliminary analysis and constant discussion between JSI and CEA the main operational parameters and design constraints of co-location of MPRR and ZPR were defined:

- Thermal power of MPRR would be limited to 5 MW with forced convection cooling during normal operation and natural convection for decay heat removal.
- Fuel flexibility will be incorporated to allow partial core replacement, facilitating testing of novel fuels and assemblies in both MPRR and ZPR. Most likely choice of fuel type for the MPRR is the common plate type fuel made of U3Si3.
- The minimum neutron flux of MPRR required for anticipated services (e.g., isotope production, materials testing) will be quantified in the future to ensure baseline performance.
- Large-volume irradiation channels for long-term material exposure, supporting screening of additive-manufactured components and other emerging materials.
- Rapid-access irradiation facilities, including proximity to hot cells or underwater manipulation capabilities, to shorten the time from irradiation to analysis.
- Temperature-controlled sample holders, with real-time temperature monitoring and active control even between irradiation cycles.
- In-situ instrumentation testing and recalibration capabilities, supporting high-precision experimental campaigns.
- The ZPR will support reactivity worth measurements using the oscillation method, with samples at various temperatures. This system is crucial for generating high-quality benchmark data for fuel and structural materials, including validation of temperature feedbacks.

- A Digital Twin of the facility will be developed from high-resolution as-built data, enabling unprecedented model fidelity and reduced simulation uncertainty. VERONICA may become the only research reactor with a full-spectrum digital reference from design through commissioning.
- Ability of neutron spectrum tailoring and multi-physics loop enabling a high level of neutron and thermal-hydraulic coupling.

4.2 Neutron spectrum tailoring and multi-physics loop

A key feature of reactor flexibility is neutron spectrum shaping, allowing diverse applications through adjustable neutron configurations. Two main approaches address this.

Ex-core Spectrum Shaping, where the neutron flux spectrum is modified externally via configurable neutron filters comprising moderators, absorbers, and secondary sources. Independent from reactor core dynamics, this method solves an inverse neutron transport problem where the goal is to identify filter compositions that yield desired neutron spectra.

In-core Spectrum Shaping, with filters placed directly within the reactor core affect reactor parameters like reactivity and neutron flux distribution. The design goal is a versatile core accommodating various filters while maintaining safety, reactivity control, and performance standards.

Additionally, the reactor should support multi-physics experiments involving coupled neutronic and thermal-hydraulic phenomena. This is achieved through a specialized in-core channel accommodating different working fluids, enabling direct neutron-thermal-hydraulic interactions. Such capabilities are essential for validating coupled simulations and benchmarking advanced reactor models, particularly relevant for Generation IV reactors employing nontraditional coolants like liquid metals or molten salts.

5 CONCLUSIONS AND FUTURE OUTLOOK

The VERONICA project represents a timely and strategic response to EU key objectives in decarbonization, industrial competitiveness, energy autonomy, and defense. By proposing a co-located Zero-Power Reactor (ZPR) and a Multi-Purpose Research Reactor (MPRR), VERONICA addresses critical gaps in the current European research reactor landscape, supporting advanced R&D, nuclear education and training, isotope production, and fuel and material testing. The dual-core configuration enables complementary and flexible experimentation, from fundamental neutronics to complex multiphysics benchmarking, within a single, accessible facility.

The initial phase of the project has focused on identifying and engaging key stakeholders, defining priority applications, and translating user needs into technical and functional reactor requirements. The resulting stakeholder-utilisation matrix confirms that VERONICA's capabilities are well aligned with a wide range of end users, including academic institutions, industrial partners, regulatory bodies, and strategic sectors such as SMR development and defence. As the project moves forward, continued collaboration and input from the European nuclear community will be essential. We invite all interested institutions and experts to engage with the VERONICA initiative and contribute to shaping a shared research platform that supports Europe's scientific, industrial, and strategic objectives.

ACKNOWLEDGMENTS

The authors acknowledge the financial support from the Slovenian Research Agency (research core funding No. P2-0073, CEA collaboration research project No. NC-25004, Young researcher project PR-13403).

REFERENCES

- [1] Pungerčič, Anže, et al. "European research reactor strategy derived in the scope of the towards optimized use of research reactors (TOURR) project." *Annals of Nuclear Energy* 211 (2025): 110963.
- [2] Fetting, Constanze. "The European green deal." ESDN report, December 2.9 (2020): 53.
- [3] Draghi, M. (2024). The Future of European Competitiveness—A Competitiveness Strategy for Europe. https://commission.europa.eu/document/97e481fd-2dc3-412d-be4c-f152a8232961_en
- [4] European Commission. (2025, January 29). *A Competitiveness Compass for the EU* (Communication COM(2025) 30 final). Brussels, Belgium: European Commission. Retrieved from EUR-Lex: doi:10.287/52025DC0030
- [5] European Commission. (2025, March 19). *White Paper for European Defence Readiness 2030*. Brussels: European Commission.
- [6] European Commission. (2024, March 5). *European Defence Industrial Strategy*. Brussels: European Commission.
- [7] European Commission. (2022, May 18). *REPowerEU Plan: Communication COM(2022) 230 final* [and accompanying Staff Working Document]. Brussels: European Commission. Retrieved from EURLex
- [8] European Commission. *Communication on the Nuclear Illustrative Programme (PINIC)*. COM(2025) 315 final. Brussels, June 13, 2025. Staff Working Document SWD(2025) 160 final.
- [9] European Commission. *Commission Announces IPCEI Design Support Hub and Endorses Nuclear Innovation Project Candidate*. Press Release, April 9, 2025, DG GROW, Brussels.
- [10] Bignan, G., Bravo, X., Lemoine, P. M., & Maugard, B. (2008). *The Jules Horowitz Reactor: A new European material testing reactor open to international collaboration*. IAEA Conference Proceedings
- [11] European Commission and Fusion for Energy. *The IFMIFDONES Project: Design Status and Main Achievements within the EUROfusion FP8 Work Programme*. *Journal of Fusion Energy* 41 (2022): Article 24.
- [12] Wijtsma, F. J., de Jong, P. G. T., & van der Linden, N. D. (2011). *Safe Management and Effective Utilization of the PALLAS Research Reactor*. In IAEA Safe Management and Effective Utilization of Research Reactors (pp. ...). IAEA.
- [13] Garoby, R., Danared, H., Alonso, I., Bargallo, E., Cheymol, B., Darve, C., ... Lindroos, M. (2018). The European Spallation Source design. *Physica Scripta*, 93(1), 014001.
- [14] Ait Abderrahim, H., De Bruyn, D., Dierckx, M., Fernandez, R., Popescu, L., Schyns, M., Stankovskiy, A., Van den Eynde, G., & Vandeplassche, D. (2019). *MYRRHA accelerator driven system programme: Recent progress and perspectives*. *Nuclear Power Engineering*, 2, 1–13.
- [15] Malec, Jan, et al. "Towards a new research reactor in Slovenia." *NENE2019 Proceedings, Portorož, Slovenija*(2019).
- [16] Snoj, Luka, et al. "A half-century of nuclear research, education and training: Story of the JSI TRIGA reactor." *Annals of nuclear energy* 214 (2025): 111122.
- [17] J. Malec, et. al., "New research reactor developments in Slovenia", Proc. Int. Conf. Nuclear Energy for New Europe '22, Portorož, Slovenia, September 12-15, Nuclear Society of Slovenia, 2022, pp. 305.1-305.9.
- [18] International Atomic Energy Agency, Feasibility study preparation for new research reactor programmes, Vienna, 2018.
- [19] Vlada Republike Slovenije, Posodobljeni celoviti nacionalni energetske in podnebni načrt Republike Slovenije, Ljubljana, 2024.
- [20] Vlada Republike Slovenije, Resolucija o dolgoročni miroljubni rabi jedrske energije v Sloveniji »Jedrska energija za prihodnost Slovenije«, Ljubljana, 2024.
- [21] Vlada Republike Slovenije, Načrt razvoja raziskovalne infrastrukture 2030, Ljubljana, 2022.
- [22] CEA Saclay, Dir. de l'Energie Nucleaire DEN, Dir. Delegee aux Activites Nucleaires, 91 - Gif sur Yvette (France) (2008) „OSIRIS Nuclear Reactors and Services Department“.
- [23] Foulon, F., et al. "Education and training on Isis research reactor." National Institute for Nuclear science and Technology (2014).