

Identified Opportunities in Utilization of the European Research Reactor Fleet as a Part of the TOURR Project

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Abstract—This paper discusses the current status of the European research reactor (RR) fleet and identified opportunities for its utilization. The data for this analysis was collected through a specific questionnaire from which a database of the European RR fleet was created. The questionnaire was designed to assess the degree of exploitation of different RR applications and to identify gaps and opportunities for future utilization. The results indicate that the European RR fleet is older compared to the world average, with no new research reactors built in Europe since 1992. The majority of RRs reported low levels of exploitation across all applications, and a desire to expand utilization was expressed by 78% of respondents. Lack of manpower, finance, and customers were identified as the main obstacles preventing expansion, while the need for more nuclear engineers was identified as a clear opportunity to attract people to the field. The findings of this study emphasize the need for actions to be taken to combat future needs and to improve the utilization of the European RR fleet. Overall, this study provides valuable insights for policymakers, industry professionals, and researchers working in the field of nuclear energy.

Keywords —Research Reactor, TOURR, European Reactors, Utilization, Research Reactor Applications.

I. INTRODUCTION

IN recent years, a significant number of research reactors in Europe have stopped its operation due to financial constraints or the aging of reactor facilities. Consequently, it has become essential to evaluate the present state of the research reactor (RR) fleet. The TOURR project has been initiated in 2019 to

address this challenge by coordinating the optimization of available research reactors in Europe.

The primary goal of the TOURR project is to devise a comprehensive strategy for research reactors in Europe and lay the groundwork for its implementation. The first phase of the project includes specific objectives, one of which is to assess the current status of the European RR fleet [1]. Based on this assessment, a strategy will be developed to modernize the reactor fleet, aimed at identifying existing gaps and potential opportunities in RR activities. This analysis will form the foundation for a comprehensive strategy to optimize irradiation time and ensure uninterrupted accessibility for experimental, educational, and production purposes.

Recently, several documents have been published that explore the use of research reactors, their future, and potential opportunities for scientific and technological applications. One such document, titled "Strategic Planning for Research Reactors" [2], primarily focuses on enhancing the use of existing research reactors and offers guidance for developing and implementing a strategic plan for new research reactor projects. Another document, "Neutron scattering facilities in Europe, Present status and future perspectives" [3], provides a detailed overview of the current status of neutron scattering applications using RR and outlines various scenarios and perspectives for the future. Notably, the document identifies a crucial gap: the need for a reactor-based source in addition to the existing spallation source in Europe. Furthermore, the document "Neutron Users in Europe: Facility-Based Insights and Scientific Trends" [4] includes a similar questionnaire analysis to the one presented in this paper, focusing on the role of each RR in shaping the European Spallation Source (ESS)

policy for innovation and access. This document also highlights gaps and opportunities related to ESS and its use in research and development.

The analysis of the current European research reactor fleet, as presented in this paper, is organized into three main sections. The first section outlines the methodology used for the analysis and explains how gaps were identified through the intended questionnaire. The second section provides an overview of the current status of the research reactor fleet and presents statistical analyses applicable to different reactor applications. The final section centers on the identification of opportunities in present and future RR activities. In conclusion, the main gaps and opportunities identified throughout the TOURR project are listed.

II. METHODOLOGY

In order to obtain data needed for this analysis, we constructed a specific questionnaire, which enabled us to create a comprehensive database of the European research reactor (RR) fleet [5]. The questionnaire was designed with a gap analysis in mind, aiming to assess each RR's application in Research and Development (R&D), Education and Training (E&T), and isotope production and its related medical applications. Through this assessment, we aimed to identify clear gaps, which would indicate potential opportunities in the specific application or field. In addition, identification of application which might become obsolete in the future could be performed.

To identify these gaps and opportunities, we relied on the expertise of both project members and authors involved in this study, in addition to the data from the questionnaire. We performed a statistical analysis of the responses obtained, searching for definitive indications of gaps. Some conclusions, especially concerning gap identification and potential opportunities, were drawn from the collective expertise and knowledge in this domain. Additionally, we obtained general information about the research reactors from the existing IAEA RR database [6].

The degree of exploitation for various RR applications was determined using the questionnaire, and initial data from the questionnaire is available in [5]. Experts and project partners identified 18 different research reactor applications during the questionnaire's creation. To determine the degree of exploitation for each application, we asked the question: "To what degree do you think this application is exploited at the RR of your institute?". Subsequently, respondents were asked a follow-up question: "Would your institute like to expand the utilization of your RR for this application?", with the option to provide further explanations for their "yes" or "no" responses.

Gaps and opportunities analysis utilized a questionnaire, combined with the expertise of project members and authors, and involved a statistical assessment of responses to identify gaps and opportunities in existing research reactor activities across various applications. The findings, presented in next Section III, will help improve the overall utilization and strategic planning of research reactors in Europe.

III. EU RESEARCH REACTOR FLEET STATUS

A. Age of EU research reactors

The IAEA RR database [6] provides publicly available general information about research reactors, including details such as power, year of construction, and type. To assess the age of the European research reactor (RR) fleet, we compared it to the world's average, as shown in Figure 1. Notably, no new research reactors have been constructed in Europe since 1992, and the majority of existing research reactors were built during the 1960-1970 period. Consequently, the average age of European RRs is 56 years, with a median age of 62 years. This indicates that the European RR fleet is relatively older than the global average, emphasizing the need for proactive measures to address future requirements. Research reactor average and median age for Europe and the world is listed in Table 1.

TABLE I
RESEARCH REACTOR AGE IN EUROPE AND THE WORLD

Analyzed parameter	Europe	World
# of operational RR	30	197
Average age (years)	56	48
Median age (years)	62	51
Year last new RR was built	1992	2016

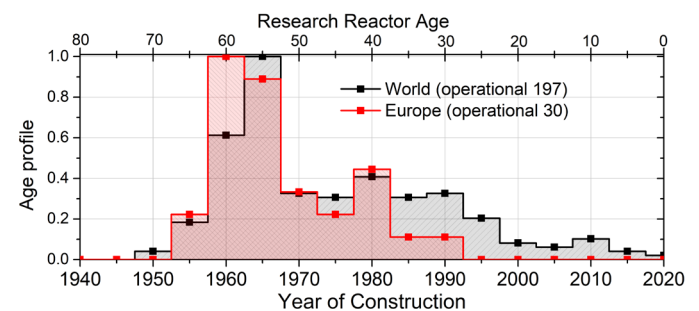


Fig. 1. Age profile of research reactors in Europe and the World (Europe included). Statistical representation of the age profile curve is presented in Table 1.

B. Degree of RR applications exploitation

The questionnaire responses were analyzed, grouping all answers regarding RR exploitation without limiting the scope to specific applications. A total of 162 responses were received, and the findings are summarized in Figure 2. The analysis showed that 43% of research reactors reported low levels of exploitation across all applications. For 31% of the RRs, the exploitation level is considered medium, while the minority of 27% indicated a high level of exploitation.

Furthermore, an average of 78% of respondents expressed a desire to expand the utilization of their respective RRs, irrespective of whether they reported low, medium, or high exploitation levels. No correlation between the current level of exploitation and the willingness to expand was observed.

In conclusion, the analysis of the IAEA RR database and general questionnaire responses, indicated the aging of European RR fleet and the need for future measures for increasing. The findings underscore the importance of

optimizing RR utilization across various applications and planning for the future demands of research reactors in Europe.

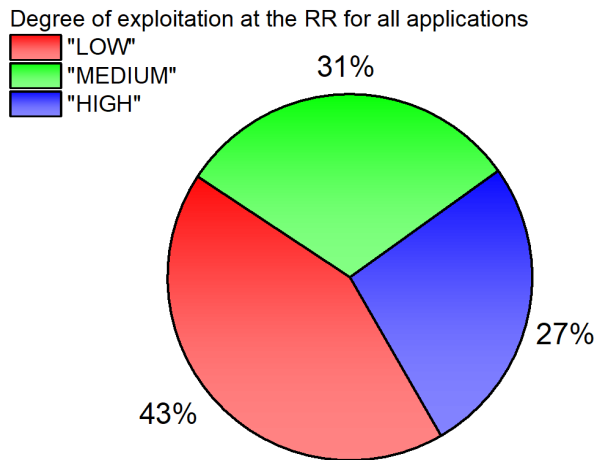


Fig. 2. Relative representation of the degree of exploitation of research reactors. Total number of answers was N=162.

Furthermore, we analyzed the average or major reason why their institute wouldn't want the expansion of their RR for individual application. Most common reason was that the reactor is already 100 % utilized in that application and no further expansion is required. Another frequent answer was that the expansion is not possible as it is limited by the reactor properties (not high enough flux, limited number of neutron ports, etc.).

C. Identification of Gaps in RR utilization

Large portion of conclusions can be obtained from the analysis of research reactors who answered "yes" to the question: "Would your institute like to expand the utilization of your RR for this application", where a follow-up question was asked: "If yes, what obstacles are preventing your institute to do so?". Multiple answers were possible, such as "Lack of manpower", "Lack of customers", etc. At first, an analysis of the results for all applications combined is presented in Figure 3. It can be observed that out of all answers the main reason for not expanding the utilization is in lack of manpower, followed by lack of finance and lack of customers.

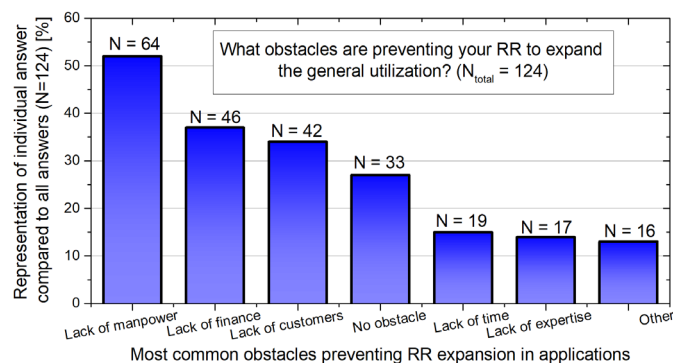


Fig. 3. Relative representation of answers to what is the reason preventing your RR to expand the utilization of all applications together. The columns within one application do not sum to 100 %, as multiple-option answer was possible.

The analysis of what is preventing the RR to expand the utilization can be performed on the level of individual

application. Individual applications in R&D were analyzed. For most applications similar to the average answer, lack of manpower was the main reason, resulting in the main gaps of RR utilization to be:

- **Lack of manpower – need for more nuclear engineers and scientists:** The „Lack of manpower“ was the most common answer to reasons for not expanding the general RR utilization. This opportunity is related to Education & Training and is further explained in Deliverable 1.4 [7].
- **Lack of long-term financing:** The “Lack of finance” was the second most common reason for not expanding RR utilization, showing a clear gap in long-term investment for operation of current RR.

There were some outliers, such as gemstone coloration and geochronology, where lack of customers was the main obstacle, marking such activity to be obsolete in the future. Another obstacle worth mentioning is the lack of financing, which is the biggest obstacle preventing the expanding in actinide transmutation, neutron scattering, neutron radiography and boron capture therapy. A clear gap of higher financing in many of the activities is observed. Another obstacle that clearly shows the gap is the „lack of time“, meaning there are not enough reactor hours to be used. One such example is the radiochemistry, however similar portion of answers was the lack of customers, meaning a more general gap can be observed:

- **Better communication to bridge the gap between customers and reactor operators:** It was observed that the number of answers for „Lack of time“ and „Lack of customers“ was the same and this issue would be fixed with communication and distribution of work.

IV. IDENTIFIED OPPORTUNITIES IN RR UTILIZATION

Based on the presented gaps, observed from the analysis of the questionnaire answers, opportunities in RR utilization can be devised. In addition, state-of-the-art research was analyzed to determine general opportunities for new future activities ranging from radiation hardness testing, nuclear fusion to nuclear-driven chemical production and processing.

Based on the identification of gaps in RR utilization three opportunities can be determined:

- **Opportunity to attract people to the nuclear field** – The analysis showed a large gap, where new possibilities for nuclear engineers and scientist are possible (e.g. NAA scientist are aging, need for transfer of knowledge). High need for employment among research reactors in Europe.
- **Opportunity for long-term financing** – With stable financing high portion of EU research reactors will be able to afford the expansion of utilization in various RR applications.
- **RR communication platform** – In the scope of the TOURR project a platform will be launched, which will make the communication between

customer and institute, operating the research reactor, easier and more direct. The platform is being launched in the final year of the TOURR project in 2023 [8].

Based on the analysis in the state-of-the-art, the identified opportunities in future RR R&D utilization are:

- Nuclear-driven production and processing of chemicals (chemical transmutations in research reactors) [9].
- Radiation Hardness Testing.
- Fusion applications (e.g. Water activation loop in research reactors [10]).
- Neutron scattering – In the future reactor-based source will be needed.
- Research in the field of fuel cells, hydrogen storage and batteries.
- Increase of silicon doping due to the increase of renewable energy.

A. Actions to implement in the long-term

One of the conclusions of our analysis is that: it can be inferred that RRs are a great resource in terms of ‘teaching’ and allowing students and young professionals to get first-hand experience. This is in contrast with the fact that the number of RRs in the EU is decreasing.

Having fewer RRs means losing opportunities for the E&T sector including a high risk for human capacity in terms of qualified RR operators and/or employees. The RR fleet should be kept numerous and equipped with state-of-art installations to be attractive for the new generation of nuclear workforce. This leads to the conclusion that having a larger pool of nuclear-educated people will represent a resource for the RRs community in need of a larger workforce to expand their E&T activities. The following actions summarized in the table are encouraged to fill the gap between the current scenario and the ideal one. Table II summarizes and prioritizes the main actions to be implemented in the long-term scenario.

TABLE II
 ACTIONS TO BE IMPLEMENTED IN THE LONG-TERM SCENARIO

1	•Continuous promotion of nuclear education
2	•Retention of nuclear-educated people in the nuclear field
3	•Retention and attraction of nuclear-educated people specifically in Europe and to EU RRs
4	•Continuous exchange with other nuclear networks and nuclear projects
5	•Modernize the EU RR fleet
6	•New RR for testing new technologies (electricity generation with high % of renewables)

In order for the EU RR fleet to be attractive for the young generations it is advisable to take into account the option of building new RRs, more modern and more accessible, focusing on cutting-edge research and being an E&T opportunity in the same research fields. A new research reactor could serve as well to test new technologies for future electricity generation using nuclear energy, together with a higher percentage of renewables. This reactor could be a micro-reactor (or SMR) in development by several companies around the world, the concepts of which have not yet been tested in real experiments (e.g. being built and operated).

This aspect will be analysed in more detail in D3.4 - Recommendations for planning refurbishment of existing research reactors or construction of new ones.

The TOURR consortium recommends that new Research Reactor focused projects should be started under the coordination of the European Union level, where all EU states will have access to a vast number of RR applications. We recommend supporting national initiatives regarding the building of new reactors (e.g. PALLAS or projects in central Europe countries). Euratom has already supported the construction of JHR and similar approach should be explored for supporting new projects. This support does not necessarily have to be financial but it can also consist in creating the adequate framework for this cooperation to take place.

These recommendations aim at recovering and enlarging the capacity to cover a large number of applications mentioned and discussed in this report. A good example is a medium-power research reactor flexible for almost all domestic applications of Science and Technology (S&T) (e.g. NAA, nuclear data measurements, neutron, and gamma irradiation,) and education & training (E&T) by being capable of performing unique experiments for future European nuclear engineers. Another is a zero-power RR, dedicated mainly to the research of reactor physics and benchmark experiments but that can also be employed for E&T.

V. CONCLUSIONS

The European research reactor (RR) fleet faces challenges due to financial constraints and aging equipment, resulting in many reactors ceasing operations recently. The TOURR project seeks to modernize the European RR fleet and optimize research reactor utilization. It aims to identify gaps and opportunities in existing RR activities, forming the basis for a comprehensive strategy ensuring optimized use for experimental, educational, and production purposes.

Data for the analysis were collected through a specialized questionnaire, creating a database of the European RR fleet. Statistical analysis revealed that the European RR fleet is relatively older compared to the global average, with no new reactors built in Europe since 1992.

In conclusion, the TOURR project is an important initiative that aims to develop a comprehensive strategy for the modernization of the European RR fleet, optimizing the exploitation of available research reactors. The analysis of the current status of the European RR fleet showed that there is a

significant need for modernization and improvement. The identification of gaps and opportunities in existing activities will form the basis for a comprehensive strategy that will define the framework for optimized use of irradiation time and uninterrupted accessibility for experimental, educational, and production purposes. With this strategy in place, it is hoped that the European RR fleet can be maintained and developed for the benefit of scientific research and development in Europe.

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