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REVIEW ARTICLE OPEN ACCESS

Supporting access to key pan-European research infrastructures and international cooperation

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Abstract. Large research infrastructures, especially nuclear ones, are extremely expensive to build and operate. Therefore, to develop expertise and competences in nuclear research is more efficient to have a limited number of complementary specialized large nuclear research infrastructures, shared by European researchers from different countries.

This paper describes three different actions to improve the European collaboration in the experimental nuclear research, namely open access to the nuclear research infrastructure of the JRC, the optimization of the use of research reactors in Europe and operation planning of the Jules Horowitz reactor currently under construction.

Supporting access to key pan-European research infrastructures strengthens research and innovation, avoiding duplication and optimising resources. It contributes to the European Research Area (ERA) and the European Strategy Forum on Research Infrastructures (ESFRI), as well as to maintaining competence in the EU, which is one of the objectives of the Euratom research and training programme.

1 Introduction

Large research infrastructures, especially nuclear ones, are extremely expensive to build and operate. Therefore, for developing expertise and competencies in nuclear research, it is more efficient to have a limited number of complementary specialized large nuclear research infrastructures shared by European researchers from different countries.

Different projects aiming at supporting the effective use of European nuclear research are running within Euratom. In this paper, three of them are described. Since 2002, the JRC has been providing access to its installations through different projects, and in 2019, a new project started, making it possible to provide financial support to the users of the JRC's nuclear research infrastructures.

In the case of the European Research Reactor (RR) fleet, the access strategies for the future are made in the TOURR project. The goal is to evaluate the current and future need for neutron sources in Europe along different science and technology axes.

Finally, the plans and access rights of the Jules Horowitz Materials Testing Reactor (JHR) are also described by the JHOP2040 project. As Euratom owns 6% of access rights to the reactor capacity, it is of utmost importance that these access rights are used effectively. The EU-JHOP2040 project is developing the first roadmaps for the use of Euratom access rights covering the first 15 years of the JHR operation.

2 Open access to the nuclear research infrastructure of the JRC

Since 2002, one of the objectives of the Euratom research and training programmes has been to maintain and further develop the scientific competencies in the nuclear area and the availability and the optimisation of the use of research infrastructures in Europe.

To fulfil this objective, while contributing to the European Research Area (ERA), the JRC has been providing access to its nuclear research infrastructures in the frame of collaborative EU research projects and agreements and dedicated JRC programmes.

The JRC's open access programmes enable scientists from EU Member States and associated countries' organisations, universities and strategic partners to carry out experiments at the world-class JRC's research laboratories. At the same time, the programmes contribute to the

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development of competencies and skills of young scientists and professionals and the development of nuclear technologies.

The infrastructures [1] where access has been provided are:

(a) ActUsLab (Actinide User Laboratory) is a facility for research on actinide science, preparation of nuclear samples and their characterisation to understand their chemical and physical properties in different environments.

(b) EUFRAT (European facility for nuclear reaction and decay data measurements) comprises accelerator laboratories for investigating neutron-induced nuclear reactions and radionuclide metrology laboratories for accurate measurements of radioactivity.

The open access programme's implementation follows the principles of the European Charter for Access to Research Infrastructures [2]. There are two modes of access: relevance and market-driven. In the relevance-driven mode, a committee composed of external experts representing the stakeholder community carries out the evaluation; the selection criteria are the relevance of scientific, educational, and socio-economic aspects of the proposals received, their relation to the JRC's programme and its strategic importance for Europe; this mode is mainly oriented to Academia and Research Institutions. The market-driven mode is mainly oriented to industry; the JRC selects the projects to be granted, and the costs are charged by the user.

2.1 ActUsLab (Actinide User Laboratory)

Actinides are key for nuclear fission technologies for nuclear energy and non-energy applications. They have very peculiar and complex chemical and physical properties. Besides their fundamental scientific interest, understanding their properties is also vital for the safety of their use in any technological application.

One of the few facilities worldwide to perform research on the basic properties of actinide materials is ActUsLab. Opening the facility to external users enhances the cost-effectiveness and, through collaboration and networking, increases the value and quality of the research and can lead to new research areas. Training the next generation of actinide scientists and technologists also contributes to maintaining and developing competencies in the EU.

The facility includes the following installations.

- **PAMEC (Properties of Actinide Materials under Extreme Conditions)**: an ensemble of state-of-the-art installations designed for basic research on the preparation, behaviour and properties of actinide materials under extreme conditions of temperature, pressure, external magnetic field, and chemical environment. The facility includes devices for measurements of crystallographic, magnetic, electrical transport, and thermodynamic properties, Mössbauer spectroscopy and surface science spectroscopy.
- **FMR (Fuels and Materials Research)**: dedicated to the synthesis and characterisation of actinide-bearing materials, up to temperatures of several thousands of degrees. It includes sample fabrication methods, encapsulation techniques and characterisation methods, such as x-ray diffraction, vibrational spectroscopy, electron microscopy, calorimetry, mass spectrometry, dilatometry, indentation, and laser heating, for the measurement of thermophysical properties.
- **HC-KA (Hot Cell Laboratory – Karlsruhe)**: laboratory consists of 24 shielded hot cells to analyse the behaviour of nuclear-spent fuel and radioactive wastes aiming to contribute to safe and cost-effective solutions for their treatment. Highly radioactive materials, including full-length light water reactor pins, can be handled at the installation. Access to HC-KA has been offered since 2020.

Since 2002, ActUsLab has delivered 1949 access units (operating days) to about 200 users, including about 45 Ph.D. students, on 144 projects (out of 237 submitted).

In the period 2014–2020, 46 projects were accepted (out of 62 proposals), including the participation of young researchers, 25 Ph.D. and 2 master's students performed experiments at ActUsLab. In the same period, 37 peer-reviewed papers resulting from the experiments performed were published.

ActUsLab collaborates as well with the key actors in the nuclear field worldwide, and it is involved in the organisation of the reference international scientific conference "Journées des Actinides (JdA)", and in the biannual actinide science school dedicated to students and young professionals.

2.2 EUFRAT (European facility for nuclear reaction and decay data measurements)

EUFRAT is a unique infrastructure that provides state-of-the-art reference nuclear data, materials and measurements for harmonisation and standardisation. The reference data and materials obtained are essential for the safe operation of nuclear reactors, safe management of nuclear waste, nuclear decommissioning, and the radiological protection of the persons and the environment. They are a reference used for other applications such as medical radionuclide production, fundamental physics, nuclear astrophysics, materials research, and cultural heritage.

The infrastructure comprises the following facilities:

- **GELINA (Neutron time-of-flight facility)**: it combines four specially designed and distinct units: a high-power pulsed linear electron accelerator, a post-accelerating beam compression magnet system, a mercury-cooled uranium target, and flight paths with measurement equipment;
- **MONNET (Tandem accelerator-based fast neutron source)**: it produces continuous and pulsed proton-, deuteron- and helium ion beams, serving as a source of well-characterised quasi-mono-energetic neutrons;
- **RADMET (Radionuclide metrology laboratory)**: it is used for accurate nuclear measurements and decay properties of radionuclides;

- **HADES (Low-level radioactivity laboratory)**: hosted in the deep-underground facility of the Belgian Nuclear Research Centre (SCK/CEN). Because of the low cosmic ray flux, in this laboratory, it is possible to detect very low amounts of radioactivity.

In the period 2014–2020, 75 Institutions, as research institutes and universities of EU Member States and associated countries to the programme, had access to EUFRAT facilities to carry out 112 projects. The projects included the participation of 28 Ph.D. and 11 master's students.

For the success of the project, the users' engagement is essential from the design phase. The projects are designed together by the JRC and the user Institution, continuing with the execution of experiments, analysis of the data, and preparation of publications. This interaction is beneficial for both Institutions, meeting the needs and requirements of the users and expanding the JRC research areas.

2.3 ACCESS (Open access to JRC nuclear research infrastructure)

To increase the impact, obtaining synergies between the JRC and indirect action of the Euratom research programme, the Commission services launched, 2019, a project aiming to enhance the scope of the existing schemes by further facilitating the mobility of researchers within EU. The project started at the beginning of February 2020, with 4 years duration.

The JRC continues offering free (of charge) access to its research facilities, promoting training and mobility activities and helping to maintain nuclear competencies in the EU. The new scheme, designed for this project, provides financial support to eligible users to cover their travel and subsistence costs.

Additionally, to the infrastructures already allowing open access, the Access project includes the laboratories in Petten (NL):

- AMALIA: Ageing of Materials under the effect of environmentally assisted stress corrosion cracking.
- LILLA: Liquid lead Laboratory.
- SMPA: Structural Materials Performance Assessment Laboratories.
- MCL: Micro-Characterization Laboratory.
- HFR-NB: High Flux Reactor Neutron Beams for residual stress measurements.

Financial support is offered to users coming from non-profit Institutions such as universities, research centres, and similar. The support can partly cover the travel and subsistence costs of users related to their access to the JRC nuclear infrastructure. Two types of user support are offered:

- short stay users, focused on the execution of approved experiments. The users are typically experts in the field, and the duration is about 10 operating days.
- Longer-stay users, primarily Ph.D. or master students, are linked to the approved experiments and with a focus on their education and training objectives. The duration of the stay can be extended to several months, receiving, in this case, a monthly allowance.

The first call for proposals was launched in July 2020, and 43 proposals were received. Three independent panels evaluated them, resulting in 18 accepted proposals for EUFRAT and 9 for the Petten laboratories. ActUsLab accepted 10 proposals holding six on a reserve list due to its own capacity to carry on the projects. Only one project was rejected, which shows the high quality of the proposals.

The impact of the COVID crisis on the project is very big. The access of the staff to the laboratories was very restricted and not allowed at all to visitors. Given the complexity of the projects, the ActUsLab projects (Karlsruhe site) had to be postponed, the first proposal could start only in September 2021, and four have started in January 2022, with all the others being prepared. The EUFRAT installation could adapt some proposals to be carried out remotely; three were performed, and two have started. The situation is quite the same in the Petten laboratories, the first project started at the end of 2021, and it is planned to start the others in 2022. After some adjustments, a second call was launched in 2021–2022.

3 Towards optimised use of research reactors in Europe-TOURR

The TOURR project is a response to the challenge of coordinating the optimisation of the exploitation of available research reactors in Europe [3], a project that started in October 2020.

The project's primary objective is to develop a strategy for using RRs in Europe and prepare the ground for its implementation. To achieve this goal, 6 specific steps have been identified.

I. Assessment of the current status of European RR fleet – Accomplished

As a starting point, there is a need to compile the inventory of existing RR. From the database created and maintained by the IAEA [4]. The information gathered under the TOURR project goes beyond what is already collected in [4]. Information, like the scope of implemented applications, scientific strength of each particular facility, user structure, instrumentation, future developing plans, actual and future needs, etc., has been collected via a questionnaire [5] and will be used as the base for deriving the strategy.

II. Estimation of future needs of RR and neutron sources

The main applications of the European RR fleet are classified into 5 categories:

(a) education and training.
(b) Basic and fundamental research and its instruments.
(c) Medical applications, including isotope R&D as well as beam applications.

(d) Material testing, including fuel, structural material and related instrumentation.
(e) Core physics testing for reactors in "zero power" installations.

III. Plan for the upgrade of the RRs fleet

Starting from the picture of the current status, which will be obtained with the questionnaire, it will be possible to suggest an updated plan to be developed for the use of the European RR fleet. The idea is to take into consideration also the fact that some major facilities are currently under construction. It is a fact that there is a need for RR increased availability because of the demand for isotope production (and the need to assure the supply), just to name one reason.

IV. Plan to maintain the fleet

Since the ultimate goal is to suggest an optimisation strategy, the analysis of potential problematic aspects will have to be performed. Information on which factors influence the sustainability of the RR will have to be gathered, spanning from component ageing to the cost of upgrades, including potential problems related to personnel turnover.

V. Developing tools for optimal use of RR fleet

The idea in this phase is to learn from other projects and initiatives that are already showing a great example of optimised use of resources and can be used as a model for the RRs fleet. Examples can be found in the coordination schedule of radioisotope production, the use by the international community of Material Testing Reactors (MTR) or also in the neutron scattering facilities coordination.

VI. Rising awareness of decision-makers and the public on the role of RR

A share of the public still sees them as nuclear power plants, often perceived negatively, while RRs are, in fact, modern research facilities providing answers to the challenges of modern society: in the field of health, energy, technology and cultural heritage, just to name a few. The suggested strategy for optimal use of RRs shall present all areas of application with emphasis on major achievements, and demonstrate how often research with neutrons led to practical applications used by everyone in everyday life.

3.1 TOURR Structure

The TOURR consortium is composed of 9 participants located in different EU countries. Six of them are RRs operators. The project is structured into four work packages as follows.

WP1 – Inventory of RR fleet

The main objectives of WP1 are:

- to collect data describing this database providing information about applications, future plans, and capacities of the RRs;
- to perform gap analysis in three domains: Research & Development, Medical applications and Education and Training.

WP2 – Assessment of needs and opportunities to support supply of medical radioisotopes

The world demand for medical radioisotopes is indeed growing: they are needed both for therapy and medical therapy applications. Furthermore, newly developed medical imaging techniques and new therapies require the use of new radio-pharmaceuticals.

WP3 – Tools for optimised of use of European research reactors

The specific objectives of WP3 are to:

- elaborate a strategy for optimised use of RRs in Europe;
- deliver the tools to support the implementation of the same strategy;
- support the planning of refurbishment of existing research reactors or construction of new ones (an assessment of to what extent existing and new RRs will fulfil the future needs);
- furthermore, crucial time gaps in the transfer between existing and future RRs will be identified.

WP 4 – Dissemination and outreach

3.2 Current status and vision

The project is currently in the second year of its implementation. It started in October 2020 and is scheduled to last until September 2023.

A survey was already conducted among European research reactors [6] and received an 84% of response rate. Data received are from Austria, Belgium, Czech Republic, France, Germany, Hungary, Italy, The Netherlands, Poland, Romania and Slovenia.

To decide who will participate to the survey, the starting point was represented by the information found in the IAEA RR database [5]. This information is public. For the task scope, facilities have been selected using the following filters: western Europe + eastern Europe + operational (Fig. 1).

A public report containing bulk considerations (to ensure confidentiality of the data transmitted to us by the RR) has been compiled and is available at this link [3]. If we consider the educational purpose of those RRs, according to the findings, most users of the RR fleet is represented by people working in the neutron activation analysis, closely followed by material scientists. Most are used by Master level experts while the private sector is dominated by R&D professionals and radiopharmaceutical experts. When it comes to technological applications, the majority of RRs involve neutron scattering and neutron activation analysis at a high level.

Left at the end, due to high importance, the majority of RRs cover the medical application field. More specifically, the production of medical radioisotopes in large quantities needed for nuclear medicine and, as a secondary focus, the production of radioisotopes for research purposes.

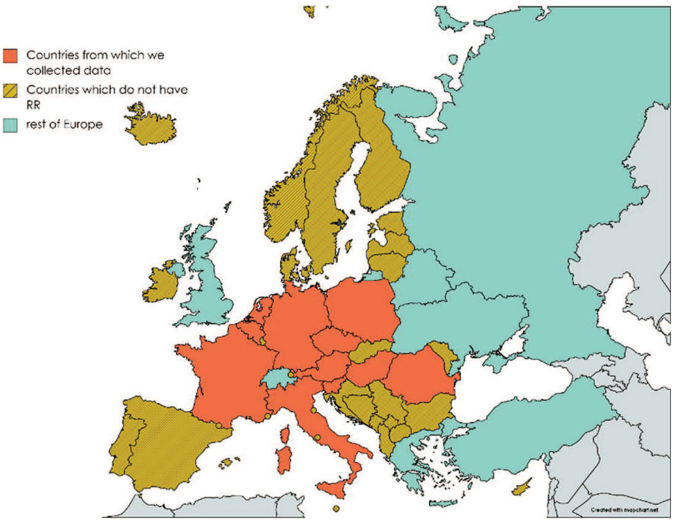

Fig. 1. Countries from which the data has been collected for the TOURR project.

About half of the RRs can satisfy all the demands they receive, and many RR already have private collaboration agreements in place to ensure continuity of supply.

Furthermore, three gap analyses on Research and Development, Medical applications and Education and Training have already been performed. Given the confidentiality required by our data contributors, we can safely observe from the analysis that there is a need to attract more people to the nuclear field since, in several cases, the lack of workforce was indicated as one of the problematic aspects.

Furthermore, once new personnel is attracted and retained to the nuclear sector (which demands some financial stability for the facilities, among other things), it should be found way to provide pedagogical tools to these people.

Finally, the RR community manifested a lack of exchange of information in some cases (understandable given the sensitivity of some data and the commercial implications). Hence the work done within TOURR acquires even more importance, in particular, if one thinks of the platform which will be realised and put online to facilitate information among RRs and between the RR community and the general public.

4 Jules Horowitz Operation Plan (JHOP2040)

Material Testing Reactors have been, for many decades, key research tools for fuel and material behaviour studies under neutron flux supporting nuclear industries, research institutes and regulators. Whatever the progress in simulation, MTRs will remain a necessity for the qualification of new fuels and materials under irradiation, notably in support of safety demonstration. Currently, in response to this need, the Jules Horowitz Reactor (JHR) is under construction. The JHOP2040 project presents a Coordination and Support Action aiming to (1) bring together with the JHR consortium of key actors, all relevant European nuclear research associations and member states that are not represented in the JHR consortium and (2) to produce strategic research roadmaps for the operation of the JHR. These roadmaps will cover the first 4-year programme and the following 11 years of operation. The outcome of JHOP2040 will be a financial and programme model for Euratom, taking into account also the governance and cost breakdown of the programmes. The JHOP2040 will strengthen and widen the JHR research network by bringing together relevant stakeholders and interest groups to identify and review their current and future needs for fuel, material and technology issues within and outside of the current JHR consortium. Extensive utilisation of the JHR via Euratom access rights and full use of the planned JHR capacity by promoting and enhancing the collaboration between potential users is the ultimate goal.

The scope of the research and training needs considered by the JHOP2040 includes activities in support of:

- current generation NPP, including component optimisation, lifetime extension, enhanced surveillance, enhanced safety of operation and inspection and waste minimisation;
- material, fuel and design development for the next generation of fission nuclear plant,including Small Modular Reactors (SMRs), Advanced Modular Reactors (AMRs), Liquid Metal-Cooled Fast Reactors (LMFRs), Gas-Cooled Fast Reactors (GFRs), Molten Salt Reactors (MSRs), and High-Temperature and Very High-Temperature Reactors (HTRs and VHTRs);
- materials irradiation and development for fusion reactors.

In this paper, we focus on planning the first four years of operation even if some references to the following 15 years will also be given.

4.1 JHR experimental capacity during operation

The start of operation for the JHR has not been announced yet, but most likely, it will happen during the next decade. The start of experimental programmes will be done in two steps. The first fleet of experimental setups will be limited to tests that are generally recognised to be the most needed. As the start of operation is known to be demanding in many ways, it is considered unnecessary to include all possible devices at the same time. It is to be expected in any case that the first experimental programmes will be started in a stepwise manner.

4.1.1 JHR experimental capacity in the start-of operation phase

The experimental capacity of the JHR will be realised in two fleets. The first fleet covers the equipment that is considered needed in the start-of-operation phase. That equipment will be Material devices MICA and OCCITANE and fuel devices MADISON and ADELINE, as well as NDE benches and neutron imaging.

The MADISON test device is designed to carry out irradiations of LWR fuel samples, during which no clad

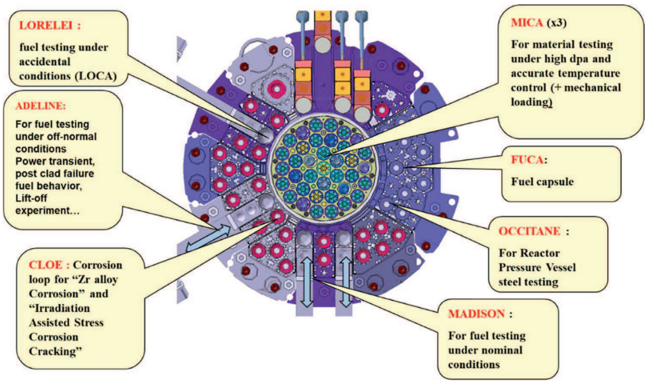

Fig. 2. JHR core experimental positions.

failures are expected. Consequently, the experimental conditions correspond to the normal operation of power reactors (steady states or slow transients that can take place in nuclear power plants). This experimental device is made of an in-pile part (holding the fuel samples) fixed on a displacement system. This system allows online regulation of fuel linear power on the samples.

ADELINE test device is able to hold a single experimental fuel rod from all LWR technologies to reproduce various experimental irradiation scenarios in which a clad failure is either a risk or an experimental objective. Similarly to the MADISON test device, this experiment is made of an in-pile part located on a displacement system in the JHR reflector and an out-of-pile water loop.

MICA test device is designed to irradiate structural materials in the core of the JHR within a fuel element. The typical temperature range is between 280 and 450 °C for the samples. Seven different locations are available for MICA devices: two in the first ring, two in the second ring and three in the third ring of the JHR core.

In the field of pressure vessel steels of NPPs, irradiations are carried out to justify the safety of this second containment barrier and improve its lifetime and, consequently the lifetime of the reactor itself. For this purpose, CEA is designing a hosting system named OCCITANE, which allows irradiations in an inert gas at least from 230 to 300 °C.

Gamma Scanning and X-ray tomography systems for NDE investigations before, between and after irradiation fuel cycles will be available in the reactor pool, in the storage pool and in the hot cells (U/HGXR).

A Neutron imaging system (NIS) will be installed in the reactor pool primarily intended to back the power ramp tests but also to secure the JHR imaging capacity and take advantage of the very different interaction of neutrons with the matter.

4.1.2 JHR experimental capacity after the start-of-operation phase

The second fleet of devices will expand the experimental capacity for e.g.:

- characterising new cladding materials, new fuel materials, new fuel assembly designs, new fuel management strategies (high burn-up, high duty) and the corresponding FP releases in LOCA situations (LORELEI device);
- a simplified fuel irradiation capsule (FUICA) in addition to the irradiation test devices;
- a mechanical loading device for irradiation experiments (MeLoDIE) to study biaxial creep online during irradiation;
- a corrosion loop to study the phenomena of irradiation-assisted stress corrosion cracking (IASCC) in the structural materials (CLOE);
- a test loop RISHI for irradiation studies in sodium at high temperatures dedicated to GEN IV structural material samples testing at different temperatures.

These devices will be available in the JHR after the start-of-operation phase.

4.2 Start-of-operation strategy for the JHR

The planning of the experimental programmes is mainly done by three JHR Working Groups for fuel (FWG), materials (MWG) and technologies (TWG). These WGs have communicated and collected the interests of not only the JHR consortium members but also those of non-JHR members in different questionnaires and made the ranking lists based on those answers.

Based on the needs listed, the main focus at the beginning of operation will be:

- for material studies: the experiments of greatest interest to the European nuclear community are mainly R&D actions related to LWRs, both those in current operation (i.e., Generation III reactors) and those in the process of building and start-up (Generation III+ reactors). The main objectives of these actions are characterisation of material behavior in the normal reactor or incidental operating situations and performance improvement. In the short-to-medium term, the community is looking to perform R&D actions which will provide information, making it possible to justify the integrity of the various structures, including in incidental situations (e.g., loss of the primary coolant for the vessel); to optimise their maintenance; and to validate their operation, including support for the evolution of the design margins and justifications for extensions to operational lifetimes.
- For fuel studies: focus will be on testing of the irradiation devices and checking the capability of each device to produce experimental results under actual irradiation conditions that are consistent with the expected uncertainties and ensure that the results obtained match correctly with the existing experimental domain for qualification, constructed with inputs from other research reactors and used for the qualification of many scientific calculation tools. This point is crucial for future experiments. In long-term planning, the investigations of fuel rod behaviour in both normal operation (including transients) and during design basis accidents (loss of coolant accidents and prompt reactivity induced accidents) will be in focus. Current fuel designs, evolutionarily advanced technology fuel designs and fuels for SMRs are all considered.

- For technologies: focus will be on qualifying tests for the experimental devices. In practice, many of these activities need to be performed before the onset of JHR operation in anticipation of using the JHR irradiation devices during the commercial period. For technological issues, it has been recognised a long list of new or improved existing technologies will require attention. Therefore, the technology development will not eventually depend on the phase of operation as much as it is for the fuel and material studies, but technologies will be developed on a constant basis or as needed.

4.3 Ways of operation of JHR experimental capacities

JHR, as a future international User Facility, is funded and steered by an international consortium gathering industry (utilities, fuel vendors, ...) and public bodies (R&D centres, TSOs, regulators, ...). The generic model of the JHR consortium is the following:

- CEA remains the owner and the nuclear operator of the nuclear facility with all liabilities.
- JHR Consortium Members are the owners of Guaranteed Access Rights to the experimental capacities in proportion to their financial commitment to the construction and with proportional voting right in the Consortium Governing Board.
- A Member can use totally or partly his access rights for implementing proprietary programs with the full property of results and/or for participating in the Joint International Programs open to non-members.
- JHR consortium membership is open to new members until the completion of the reactor.

CEA is encouraged by the consortium to enlarge JHR membership and, as of early 2022, the present member's list of the JHR consortium is the following:

CEA (France), EDF (France), FRAMATOME (France), TECHNICATOME (France), AREVA.SA (France), EUROPEAN COMMISSION, SCK-CEN (Belgium), CVR-UJV (Czech Republic), VTT(Finland), CIEMAT(Spain), STUDSVIK (Sweden), DAE(India), IAEC (Israel), NNL (UK), CGN(China).

Let us illustrate how the European Commission could tell us its Access Rights for the benefit of European Member States.

The EC (Euratom-JRC) – considering its contribution to the construction – gets:

- 6% of guaranteed Access Rights to JHR experimental capability for the whole life of operation of the reactor;
- 6% of voting rights in the JHR Consortium.

Regarding the utilisation of the Access Rights, they can be cumulated to some extent from one year to the following in order to implement greater research programs in one specific year (either proprietary program and/or Joint program (including shared with other Members).

The Operation Phase of the reactor will be partitioned into 4-year operation periods and shall be managed in consideration of the Reference Operation Plan (ROP) drawn up by the project leader for each four-year period and validated by the Governing Board.

To illustrate the Access Rights in the comprehensive unit as the quantity of experiments, let's converse Access Rights (AR) to Access Units (AU) regarding the experimental capacity of the JHR and the various factors associated with each experiment type. These Access units have to be seen as some "units of account" for the use of neutron flux and experimental capacity.

Let us consider, as an example – see Figure 2, the following experiments distribution in JHR core and reflector representative of the present developments: each experiment represents a number of Access Units depending on different parameters as indicated later on.

The weighted analysis of each experiment versus various factors, such as neutron flux, volume, complexity, and impact factors, is presented in the table below. This weight is taken as a reference Access Unit of the experiment for one cycle. This assessment of the use of Access Rights to perform experiments in JHR depends on various factors.

To translate these Access Rights to Access Units for each experiment, we need to take into account:

- the large variety and the specificities of these experiments,
- the number of experiments performed per year.

To illustrate such approach, the following example of possible weighting per type of experiment is considered in Table 1.

4.3.1 Example of experimental possibilities for European Commission with 6% Access rights

With the JHR configuration and operation described above, 6% of Access Rights represents about 78 Access Units per year (6% of 1318).

So, the EC, with its 6% Access Rights, can have access each year to:

- 7 to 8 Ramps type experiments using ADELINE device,
- or 6 Fuel loop irradiation type experiments using MADISON device,
- or 3 Material capsule-type experiments (Tab. 2).

5 Conclusions

Supporting access to key pan-European research infrastructures strengthens research and innovation, avoiding duplication and optimising resources. It contributes to the European Research Area (ERA) and the European Strategy Forum on Research Infrastructures (ESFRI), as well as to maintaining competence in the EU, which is one of the objectives of the Euratom research and training programme.

The current scheme of open ACCESS to JRC's infrastructure helps to bridge the gap between high and less wealthy institutions in the EU. The selection procedure, based on the scientific merit of the proposals and including feasibility assessment, as well as the strong collaboration of JRC staff members with users, are key factors for the success of the programme and its outputs. The number of participating organisations in previous schemes and the

Table 1. Preliminary weight factors of different experiment types in the JHR.

Kind of experimentation	Fixed part			Variable part			Impact factor (Fuel consumption, performances, . . .)	"Weight" total
	Neutron flux factor	Equipment complexity factor	Utilities (water, electricity, . . .)	Volume factor	Operation complexity factor	Services (NDE, FP lab, hot cells, . . .)		
MADISON	1	3	2	1	3	2	–	12
ADELINE	1	3	1	1	2	2	–	10
MICA	1	2	1	1	2	0	1	8
Specific MICA	3	2	1	1	2	1	2	12
LORELEI	2	3	2	1	3	3	–	14
OCCITANE	1	1	0	3	1	0	2	8
CALIPSO	3	2	2	2	3	3	1	16
CLOE	1	3	2	1	2	2	1	12
Fast reactor support	3	3	2	2	3	3	–	16
Boiling device	1	2	1	1	1	2	–	8

Table 2. Example of the JHR loading plan.

Example of loading plan A.U. = Access Units			
Type of experiment	Associated Access Unit per experiment and per cycle	Number of JHR locations for the type of experiment considered	Cumulated number of Access Units per year (on the basis of 7 cycles per year)
Fuel ramps studies (ADELINE)	10	3	210
Fuel loop steady-state studies (MADISON)	12	2	168
Fuel loop for LOCA studies (LORELEI)	14	0, 3 (we consider only 3 LOCA tests per year)	30
Fuel capsule studies (FUCA)	10	4	280
Material capsule studies in core (MICA)	8	3	168
Advanced MICA in core	12	2	168
RPV studies in reflector (OCCITANE)	8	2	112
Corrosion studies (CLOE)	12	1	84
FR material studies	14	1	98
TOTAL	100		1318

JRC agreements with other strategic partners ensure the project outreach in the specialised scientific community.

The strategic planning for optimising the use of the research reactors is ongoing at the same time when one of the most important future research facilities, namely the JHR, is under construction. The TOURR project has six specific steps that are used to ensure that the available reactor capacity is used with the maximum advantage for not only nuclear research but also medical and education and training. On the other hand, the JHR will aim at a new generation of research capacity with a wide experimental device fleet under construction. The JHR will be one of the most important research facilities not only in Europe but also in the world- widely and currently, the operation planning in parallel with the construction is taking the various needs into consideration. Euratom's share of the future capacity will benefit the whole Euratom society eventually.

The experiences gathered in the implementation of open access projects in previous and current Euratom research and training programmes are a very good basis to be used for the design of future schemes for all kinds of nuclear facilities.

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Conflict of interests

The authors declare that they have no competing interests to report.

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Data availability statement

This article has no associated data generated and/or analyzed.

Author contribution statement

Victor Esteban-Gran is the author of the text handling the project "ACCESS". Gabriel Pavel is the author of the text handling the project TOURR. Petri Kinnunen is the main author and Gilles Bignan the co-author of the text handling the project "JHOP2040" and the JHR access rights.

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