Nuclear Science

Objective

To support Member States in strengthening their capabilities in the development and application of nuclear science as a tool for their technological and economic development. To support Member States in enhancing sustainable operation, including effective utilization, of research reactors and implementing new research reactor projects and nuclear capacity building programmes based on access to research reactors.

Nuclear Data

The Agency's Isotope Browser app reached 120 000 single-user downloads in over 140 countries (Fig. 1). The Agency prepared the source code for an open source release, enabling users to contribute to its development.

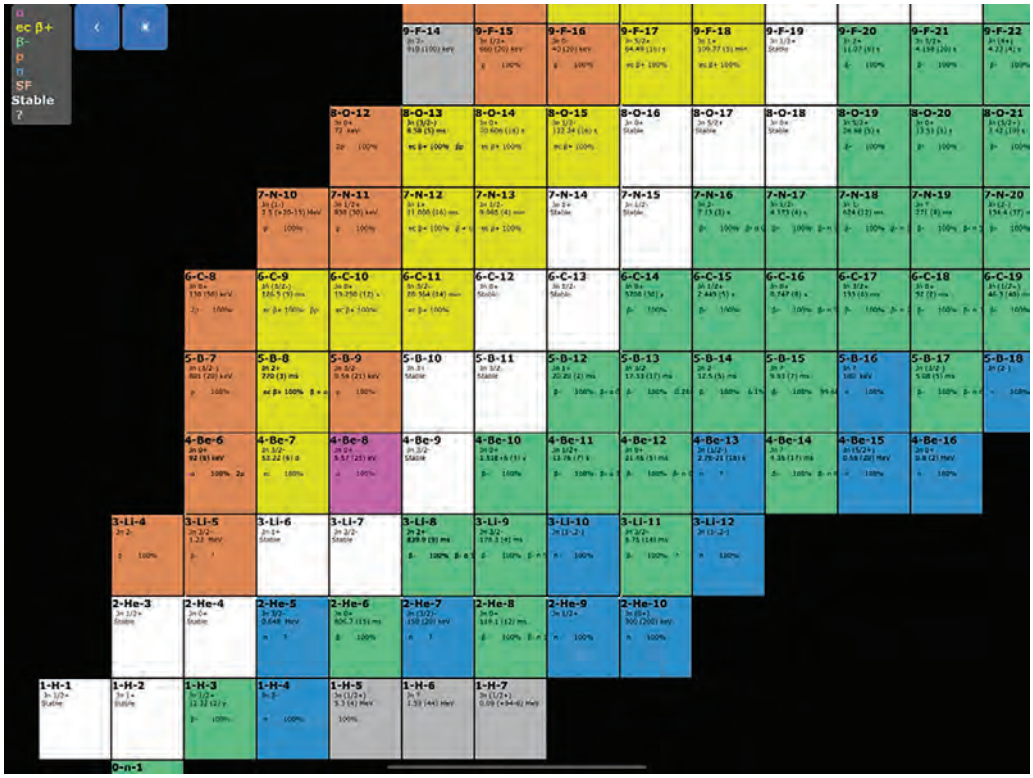


FIG. 1. Isotope Browser is an Agency app that can be installed on smartphones. It gives the most important properties for more than 4000 nuclides. A LiveChart of Nuclides, with zooming and tapping enabled, and a periodic table of elements are included to allow easy selection and navigation.

The Agency published a special issue of *Atomic and Plasma–Material Interaction Data for Fusion* with ten articles reviewing the outcome of a coordinated research project (CRP) entitled 'Plasma–Wall Interaction with Irradiated Tungsten and Tungsten Alloys in Fusion Devices'.

A new CRP entitled 'Hydrogen Permeation in Fusion-Relevant Materials' was launched to provide experimental and theoretical data on hydrogen permeation in fusion reactor wall materials and components. The data obtained through this CRP will be used in benchmarking of modelling codes for hydrogen permeation in fusion relevant conditions.

Research Reactors

Utilization and applications of research reactors

The Agency launched a new neutron imaging e-learning course that addresses the broad applicability of neutron imaging, from the fundamental principles that govern its use to new and emerging experimental techniques.

In cooperation with the Australian Nuclear Science and Technology Organisation (ANSTO), the Agency held the first iteration of the Regional Training Course on Supporting Women for Nuclear Science Education and Communication: A Continuing Education Program for Female University Science Teachers and Science Communication Professionals. The course focused on the role of nuclear science in the global endeavour to achieve the Sustainable Development Goals.

New research reactor projects, infrastructure development and capacity building

The Agency signed a host agreement with the Czech Technical University in Prague and guest agreements with the Belarusian State University and the National Centre for Nuclear Science and Technology of Tunisia on the Internet Reactor Laboratory (IRL) project in Europe. The IRL project provides nuclear engineering students and young specialists with an opportunity to participate in live reactor experiments on-line.

The Agency supported the workshop in Belgium and France on capacity building in research reactors for Member States in Africa and the Asia and the Pacific region, organized jointly by the IAEA-designated International Centres based on Research Reactors (ICERRs) at the Belgian Nuclear Research Centre (SCK·CEN) and the French Alternative Energies and Atomic Energy Commission (CEA). Thirteen participants from ten Member States visited research reactors and ancillary laboratories in Belgium and France, discussed research reactor projects in their countries and identified collaboration opportunities and training needs that could be addressed using the ICERR facilities of the CEA and SCK·CEN.

Research reactor fuel cycle

At the Technical Meeting on Global Capabilities for the Production and Manufacture of Non-High Enriched Uranium Molybdenum-99 Targets, participants shared insights into the progress towards production of molybdenum-99 without high enriched uranium.

The Technical Meeting on Current Practices and Developments in Research Reactor Spent Fuel Dry Storage provided a forum for owners, operators, designers and regulators of research reactors and spent fuel management organizations to discuss and exchange information, experiences and practical knowledge related to dry storage of spent research reactor fuel.

The Agency published *Material Properties of Unirradiated Uranium–Molybdenum (U–Mo) Fuel for Research Reactors* (IAEA-TECDOC-1923), describing the material properties of all unirradiated uranium–molybdenum fuel constituents that are essential for evaluating the fuel's performance and safety for research reactors.

Research reactor operation and maintenance

Two publications were issued on the operation and maintenance of research reactors. *Condition Monitoring and Incipient Failure Detection of Rotating Equipment in Research Reactors* (IAEA-TECDOC-1920) includes fundamentals on condition monitoring of rotating equipment, standards and guidelines, implementation strategies, current status and recent developments, as well as the experience gained from projects carried out in Member States. *Guidelines for the Operation and Maintenance Assessment for Research Reactors (OMARR)* (IAEA Services Series No. 44) provides information on the preparation, implementation and reporting of OMARR missions, including follow-up missions.

Accelerator Applications

The conclusions of the Technical Meeting on Advances in Boron Neutron Capture Therapy will contribute to the update of the publication *Current Status of Neutron Capture Therapy* (IAEA-TECDOC-1223), issued in 2001.

The new publication *Modern Neutron Detection* (IAEA-TECDOC-1935) covers the current state of the art of neutron detection and provides a medium term outlook on neutron detection technology development, including new materials, detector electronics and spectral unfolding techniques.

The Agency launched a new e-learning course entitled 'Introduction to Electrostatic Accelerators: From Basic Principles to Operation and Maintenance'. The course provides theoretical and practical information on the effective and safe operation and maintenance of accelerators, ion sources, other facility systems and components, and associated instrumentation, as well as on operational procedures.

Through partnership agreements with Elettra Sincrotrone Trieste in Italy and the Ruđer Bošković Institute in Croatia (Fig. 2), 74 days of beam time were allocated to ten research

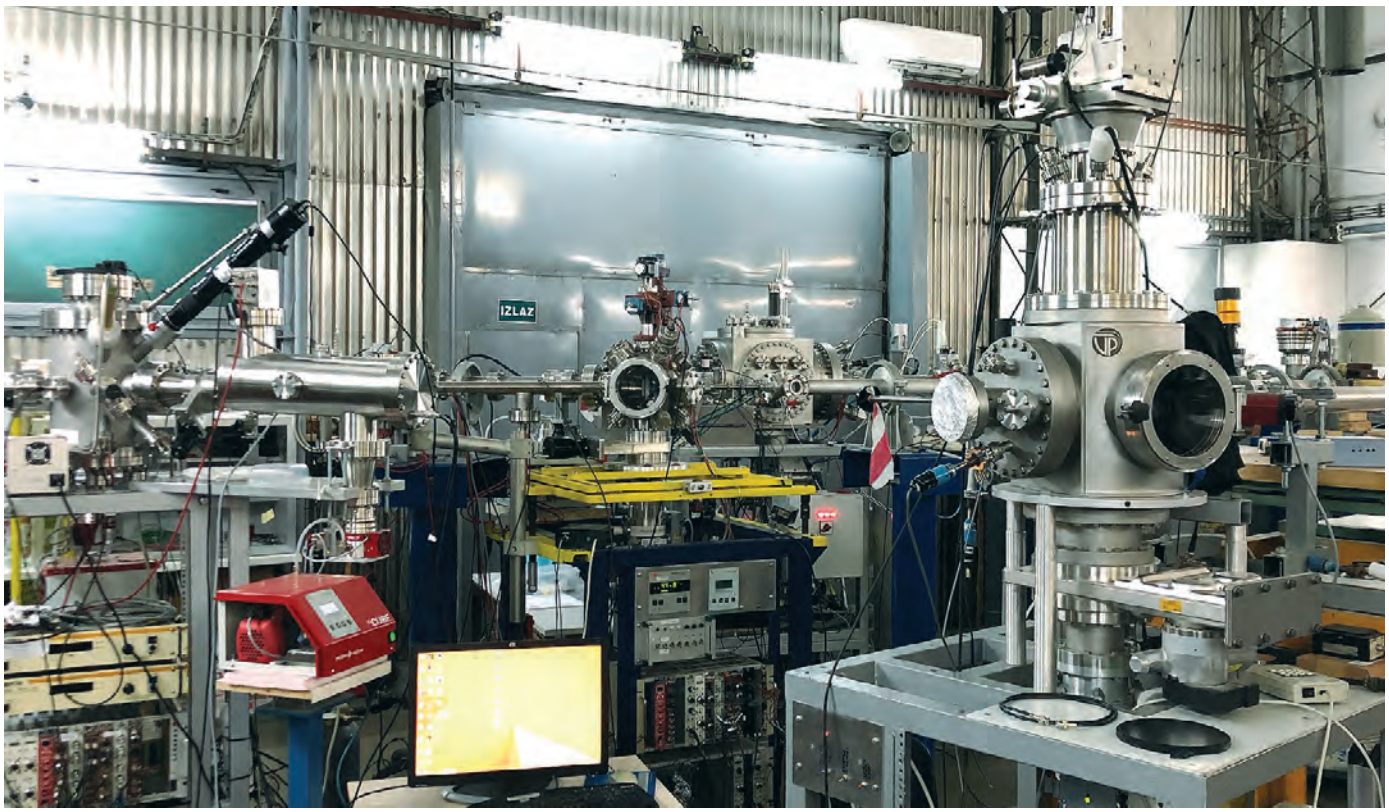


FIG. 2. The 'He Ion Source and DiFU Dual-Beam Facility', installed with Agency support in Croatia's Ruđer Bošković Institute, ensures access to experiments in the field of materials research for fusion, among other research areas.

groups from six Member States using the joint IAEA–Elettra Sincrotrone Trieste X ray fluorescence experimental end station, while 26 days of beam time were allocated to nine research groups from five Member States using the Agency co-funded ion beam facility infrastructure. The areas of research ranged from fusion materials research, detector testing and life sciences to environmental studies, electrochemistry and cultural heritage.

Nuclear Instrumentation

The Agency project entitled 'Rapid Environmental Mapping with UAV, Phase II: Operational Support' supporting Fukushima Prefecture, Japan, was completed with the development of equipment and a methodology specifically for the use of instrumented unmanned aerial vehicles (UAVs). Under the project, the Agency developed and provided a complete UAV based instrumentation system and assisted in trial radiological mapping as well as in training relevant Prefecture staff in using the equipment (Fig. 3).

The Agency launched a proficiency test for nuclear and related analytical techniques laboratories involved in the analysis of various samples and materials. The invitation was accepted by 101 laboratories in 55 Member States, which were provided with the Agency samples for analysis.

FIG. 3. A new technology using drones, developed by the Agency for use by the authorities of Fukushima Prefecture, Japan, allows for radiological measurements. (Photograph courtesy of Fukushima Prefecture.)

Nuclear Fusion

The Agency published *Challenges for Coolants in Fast Neutron Spectrum Systems* (IAEA-TECDOC-1912), which evaluates the different coolant options considered for nuclear applications with a fast neutron spectrum, such as fusion, fission and accelerator based systems; presents the latest information in the field; and identifies further research needs.

The Agency's new CRP entitled 'Pathways to Energy from Inertial Fusion: Materials Research and Technology Development' is the fourth in a series of CRPs on this topic. The project will continue to facilitate international cooperation and information exchange on inertial fusion research and development, and will promote the use of inertial fusion technologies in fundamental science and industrial applications. The results of a previous CRP in the series are captured in a new publication entitled *Pathways to Energy from Inertial Fusion: Structural Materials for Inertial Fusion Facilities* (IAEA-TECDOC-1911).

The Agency launched its first CRP in the area of accelerator based techniques for materials research relevant to fusion technology, entitled 'Development and Application of Ion Beam Techniques for Materials Irradiation and Characterization relevant to Fusion Technology'. The project will assist the international ion beam analysis community in coordinating research efforts aimed at understanding aspects of ion induced radiation damage in materials relevant to fusion technology as well as their analysis and interpretation.

The First Joint IAEA–ITER Technical Meeting on Safety and Radiation Protection for Fusion Reactors focused on safety and radiation protection issues relevant to experimental fusion facilities, with a focus on ITER.

CASE STUDY

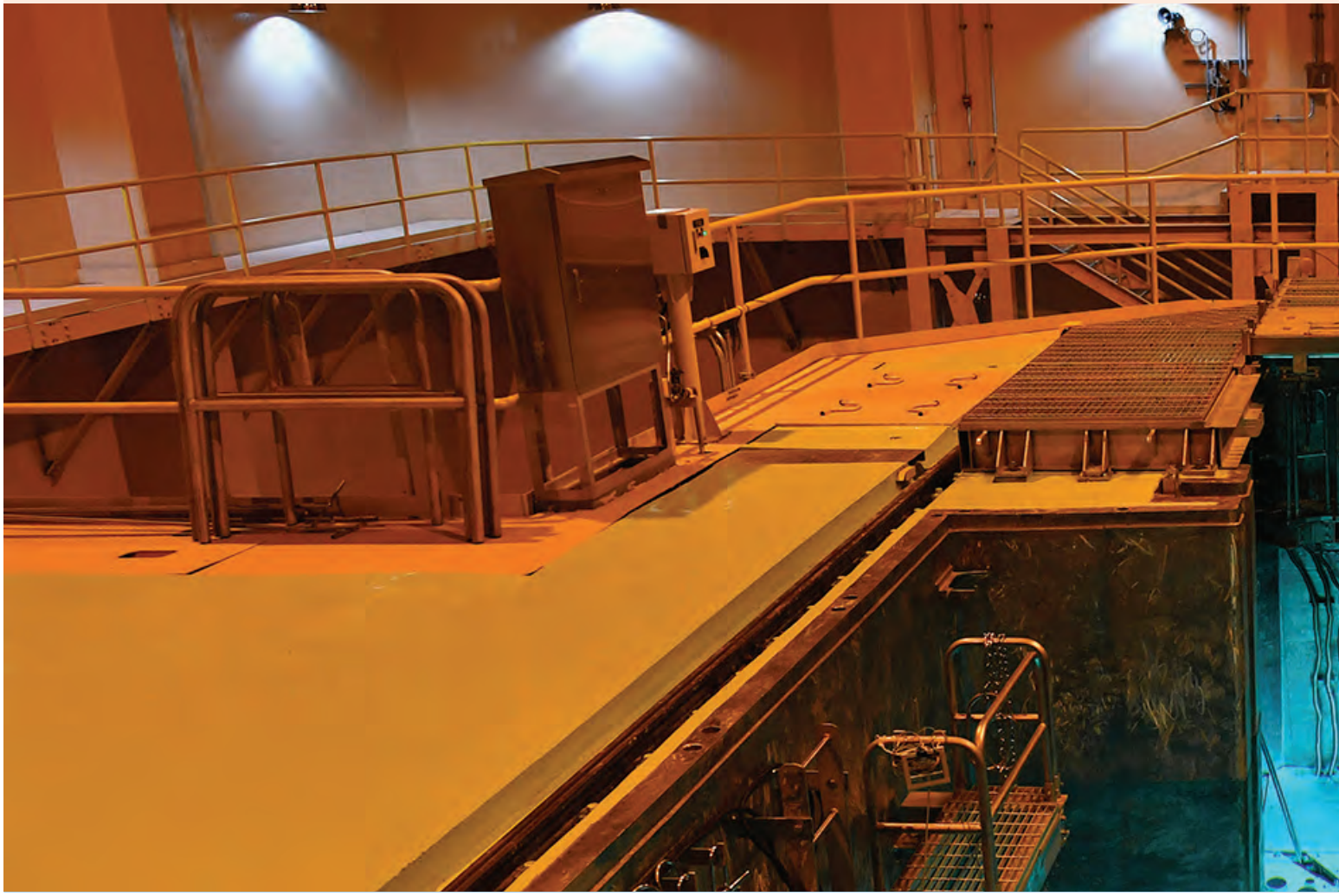
Providing Access to Nuclear Research to All Countries: The ICERR Programme

Research reactors have been centres of innovation for nuclear science and technology since the inception of nuclear energy. They are used in materials research and modification, and radioisotope production. The IAEA-designated International Centre based on Research Reactors (ICERR) initiative enables researchers from various countries to have hands on training and the opportunity to conduct experiments and work at state of the art facilities in other countries.

In the five years since the French Alternative Energies and Atomic Energy Commission (CEA) became the first ICERR in 2015, it has hosted around 60 events under the ICERR scheme, including scientific visits, workshops, hands-on training and joint research and development activities. In its work with ICERR affiliated scientific research institutes in Algeria, Indonesia, Jordan, Morocco, Slovenia, Tunisia and the United Arab Emirates, the CEA's experience demonstrates how the ICERR programme acts as a force multiplier in fostering advanced training as well as joint research and development around the world.

Under the ICERR programme, scientists from Algeria had a chance to collaborate with the CEA and to access CEA facilities, including its dosimetry laboratory in Cadarache. Algeria operates two research reactors for uses such as isotope production, radiography and training.

"Research reactor specialists from Algeria increased their knowledge in nuclear safety and methods for measuring neutron fluxes and spectra," said Abdelhamid Mellah, Head of the Algerian Atomic Energy Commission (COMENA). "They will use this knowledge to



An Agency initiative enables researchers from different countries to conduct experiments and work at research reactor facilities in other countries, including at the Jordan Research and Training Reactor.

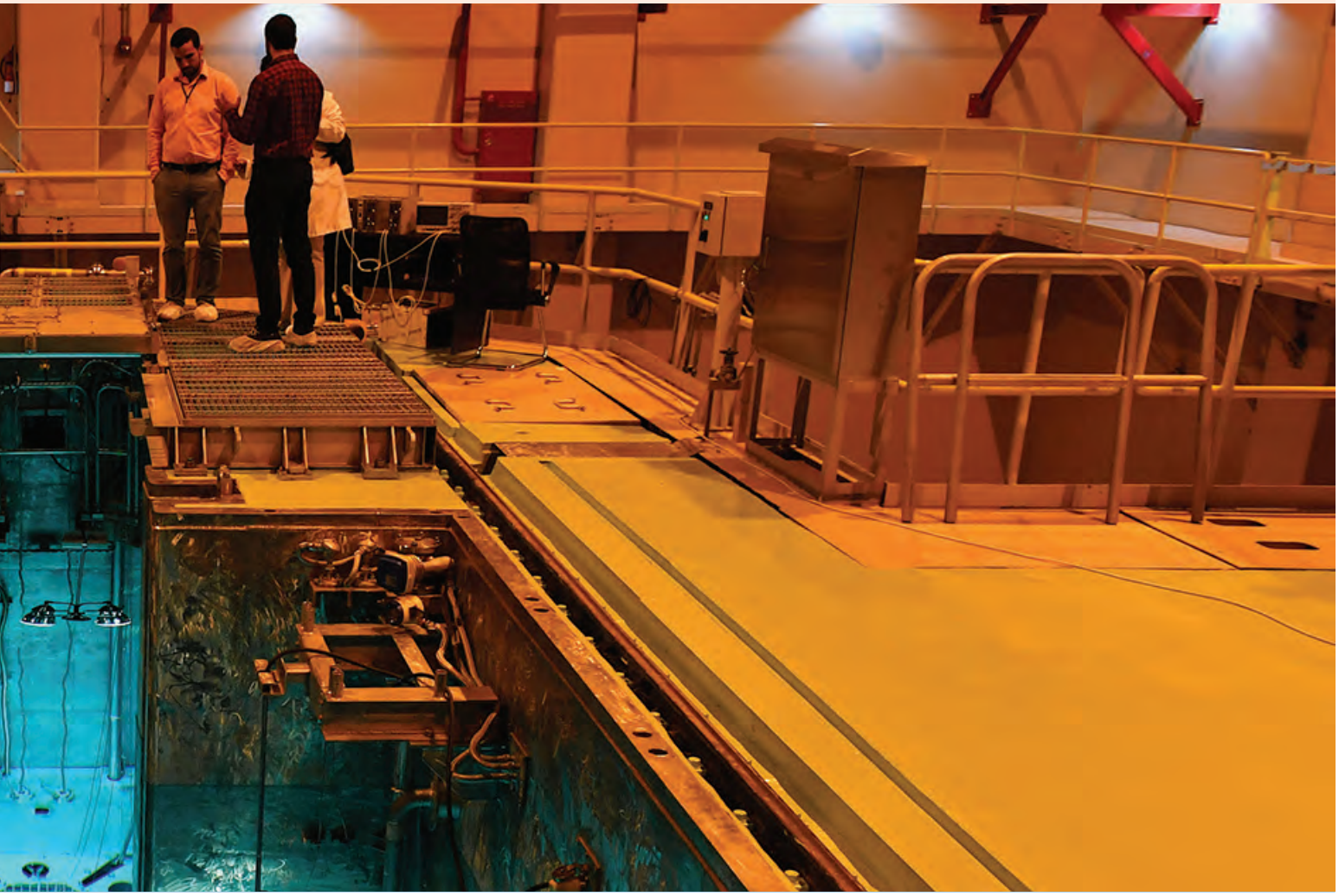
enhance our own reactor safety and utilization, including radioisotope production, material research and optimization of fuel consumption."

Over the past five years, the CEA has organized 66 scientific visits for scientists from Algeria, Azerbaijan, Bangladesh, Indonesia, Israel, Jordan, Kenya, Malaysia, Myanmar, Philippines, Poland, Saudi Arabia, Turkey and Viet Nam. It has also hosted 13 interns from Argentina, Benin, Jordan, Mauritania, Tunisia and Viet Nam. In 2020, an ICERR tour was organized jointly by CEA and the Belgian Nuclear Research Centre (SCK·CEN) for 13 participants from ten countries.

"We consider human capacity building key in the peaceful use of nuclear energy and sciences," said Gilles Bignan, International Affairs Manager at the Jules Horowitz Reactor. "In the last five years, CEA has been able to successfully collaborate with institutes from seven countries to create and enhance links between scientists and engineers and promote research."

A Slovenian researcher recalls his experience using the scheme to advance his work on characterization of the gamma radiation field inside a nuclear reactor: "ICERR has enabled me to get in contact with the leaders in my research field, both on an experimental and modelling front. This helped me immensely with my PhD thesis about novel techniques in radiation measurements and simulations related to reactor materials, safe operation and decommissioning, and nuclear fusion research. It also was a great opportunity to be involved in research in laboratories abroad, as well as to sample and experience the culture."

About 230 research reactors currently operate in 54 countries. ICERRs include research reactors and associated facilities in Belgium, France, the Republic of Korea, Romania, the Russian Federation and the United States of America.



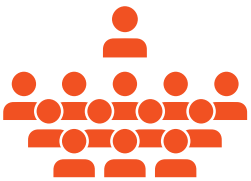
Nuclear Techniques for Development and Environmental Protection

participation in

38 **conferences** and **symposiums**

51

technical, consultancy and **research coordination meetings**



81

coordinated research projects

88

webinars

20

databases in total

2 new

databases in 2020

ORION • IMAGINE

2020

Human Health Campus

93 865
users

including **20 076**
returning users

231
Agency web articles and newsletters

29
publications

37
guidelines, manuals and protocols

273
journal articles

37
active Collaborating Centres
within the Department of Nuclear Sciences and Applications

40
e-learning and on-line courses