Exploring research reactors and their use

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For over 60 years, research reactors have provided the world with a versatile tool to test materials and advance scientific research, as well as to develop and produce radioactive materials that are key to diagnosing and, in some cases, treating diseases. There is a wide array of designs for research reactors and an even wider array of applications that offer socio-economic benefits to help countries worldwide achieve their sustainable development objectives.

More than 800 research reactors have been built to date. Although many have been shut down and decommissioned over the years, 224 continue to operate in 53 countries. Currently, 9 new research reactors are under construction, and more than 10 have been constructed over the last 10 years. Since most research reactors were built in the 1960s and 1970s, half of the world's operational research reactors today are more than 40 years old and around 70% are over 30.

What are research reactors?

Research reactors are small nuclear reactors that are primarily used to produce neutrons, unlike nuclear power reactors, which are larger and used to generate electricity. Compared to nuclear power reactors, research reactors have a simpler design, operate at lower temperatures, require far less fuel and, therefore, result in far less waste. Given their important role in research and development, many research reactors are housed at university campuses and research institutes.

The power of research reactors is designated in megawatts (MW), with 1 MW being equal to 1 million watts, with watts being a unit of power. The output of research reactors ranges from 0 MW, such as that of a critical assembly, up to 200 MW, which is in contrast to the 3000 MW (also denoted as 1000 MW (electrical)) of a large nuclear power reactor unit. However, most research reactors have an output of under 1 MW.

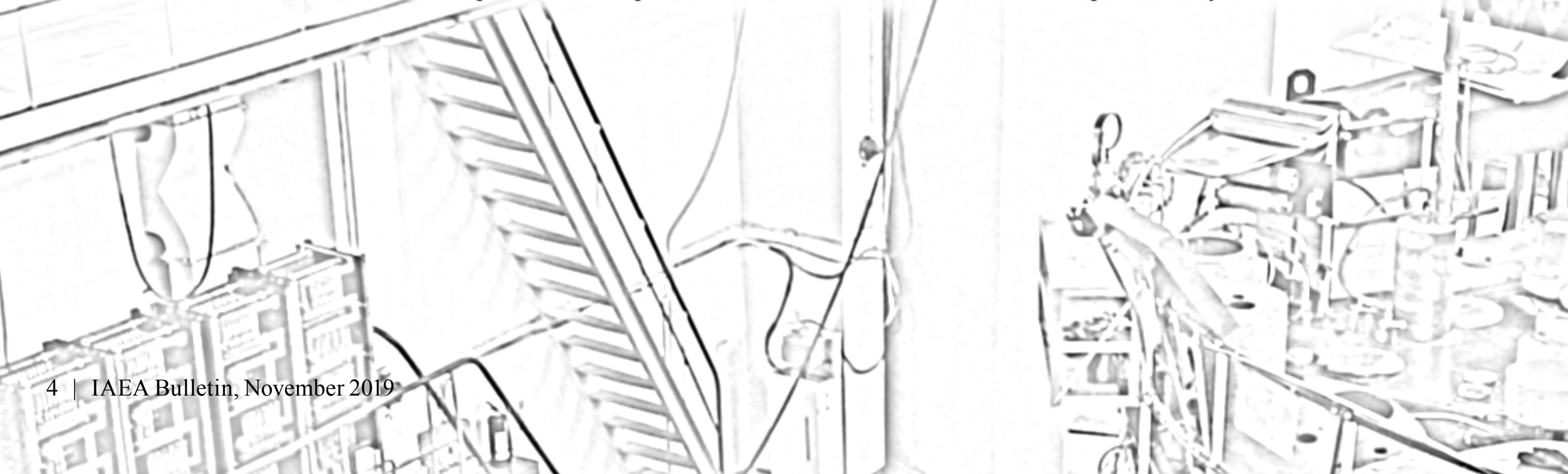
How are research reactors used?

The neutrons — subatomic particles found in almost all atoms — produced by research reactors are useful for scientific studies at the atomic and microscopic levels. They are used to produce radioisotopes for medicine and irradiate materials for the development of fission and fusion reactors, among other applications. These particles are primarily used in areas such as industry, medicine, agriculture, forensics, biology, chemistry and geochronology.

Unlike power reactors, research reactors are also well suited for education and training. This is due to their lower complexity, which means their systems and overall designs are simple and easy to access, thereby making it possible to safely simulate different reactor conditions. Research reactors can be used to train reactor operators, maintenance and operational staff of nuclear facilities, radiation protection personnel, regulatory personnel, students and researchers.

Some of the specific uses of research reactors

Research with neutrons started after physicist James Chadwick discovered neutrons in 1932. By the mid-1950s, the use of neutrons in research had become more widespread, in particular as researchers began applying neutron scattering techniques. Today, neutrons produced by research reactors are



used for a variety of purposes. Here are a few of their applications.

Neutron scattering is an analysis technique for understanding the structure and behaviour of solids and condensed matter. As neutrons interact with atoms in matter, their energy and other properties may change. These changes can be used to study the structure and dynamics of matter. The properties of neutrons also make them particularly useful for studying hydrogen, small and large objects, and a myriad of materials, including magnetic materials. This is useful for understanding how bones repair themselves, studying proteins in the brain, improving batteries and creating magnets, among others.

For **analyzing materials**, neutrons and X-rays are often combined, as they provide complementary information. Neutrons are sensitive to lighter elements, particularly to hydrogen in water and to biological material, whereas X-rays are more sensitive to heavier elements, like iron in steel. Combining neutron and X-ray techniques allows for greater sensitivity to all components of a sample or object.

Using neutrons for **materials research** and materials development contributes to scientific understanding and the development of technologies across a variety of areas, from electronics to medicine and construction materials for extreme conditions, such as equipment for work in space and nuclear power plants.

Research reactors also provide neutrons that can be used to help researchers characterize cultural heritage objects, such as paintings and monuments. Neutron-based techniques can distinguish between different types of materials used in artwork, such as paint, and the elemental composition and texture of artefacts, such as rocks. These methods are referred to as '**non-destructive testing**', because they allow researchers to study the objects without damaging them.

Neutron irradiation can also be used to create new materials with useful properties. For example, silicon is irradiated with neutrons to change its conductivity for use in high power application semiconductors.

Research reactors are also used for **radioisotope production**. Radioisotopes are unstable elements that regain stability by undergoing radioactive decay. During the decay process, various kinds of radiation are released, which can be used in medicinal or industrial applications.

One of the most common uses of radioisotopes is for diagnosing and treating health conditions like cancer and cardiovascular diseases. The most widely used radioisotope in medicine is technetium-99m, which comes from the radioisotope molybdenum-99 and is used for diagnostic imaging (see page 12).

Supporting the use of research reactors

The IAEA has decades of experience in promoting the use of research reactors worldwide. It assists countries at all phases of a research reactor project, from planning, building, commissioning and operating, to end-of-service decommissioning and dismantling. The IAEA also supports countries in optimizing the efficient and sustainable use of their research reactors (see page 20) and helps countries without research reactors to gain access to them so that they can also benefit from these powerful tools. This support comes in the form of training, workshops, sharing expertise and best practices and peer review services (see page 22), as well as published guidance documents, standards, remote access for education and e-learning courses. The IAEA also supports countries in addressing safety and security at research reactors, including the safe and secure conversion of research reactors from high enriched uranium fuel to low enriched uranium fuel (see page 26).