






Regional Profile for Europe and Central Asia for 2022–2027

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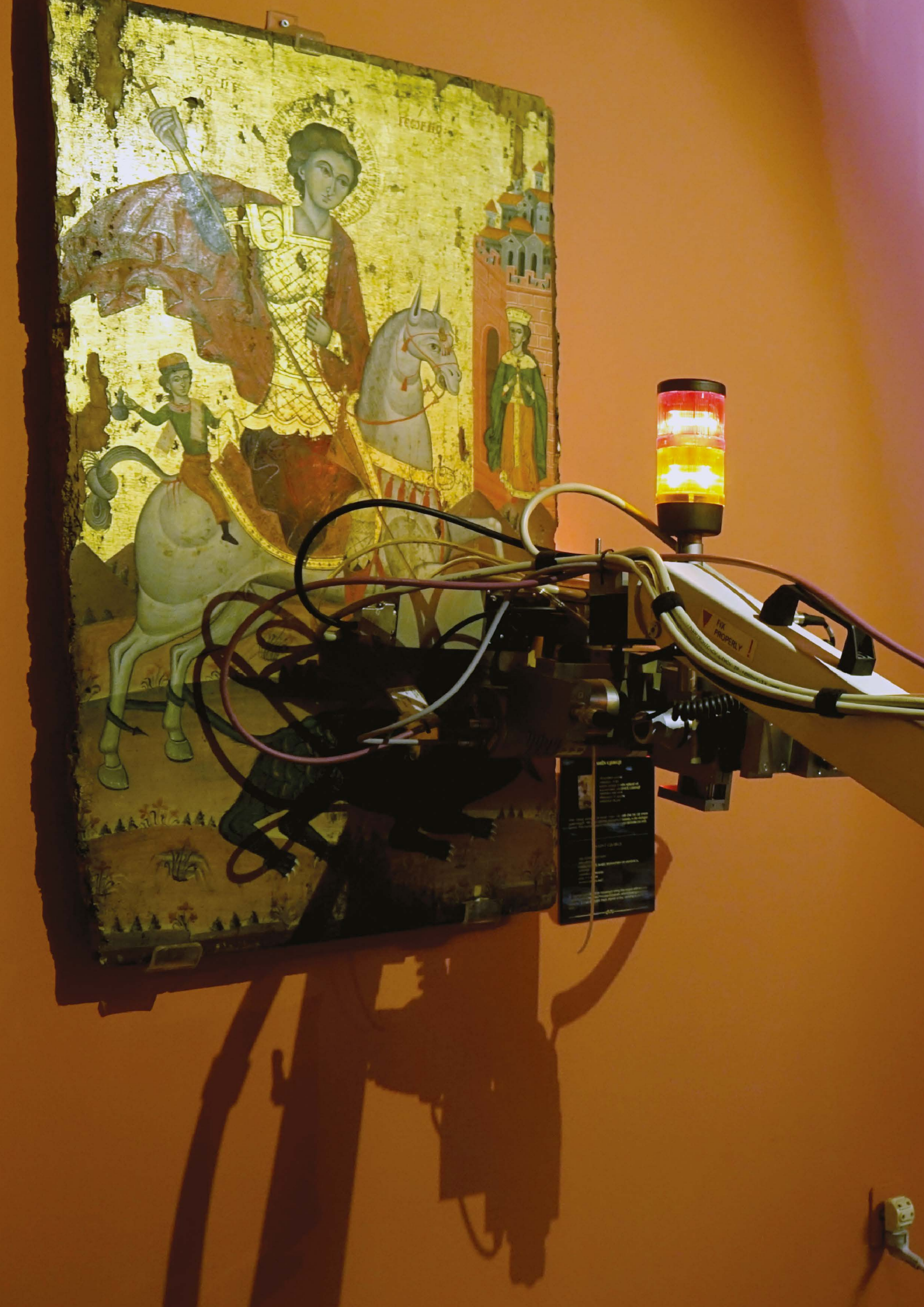
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Executive summary

This document is an updated version of the 2009-2017 Regional Profile for Europe. The profile was used to support the elaboration of the 2009–2013, 2014–2017 and 2018–2021 regional technical cooperation programmes for the region. This updated version covers the period 2022–2027 and will serve as reference for the formulation of regional projects and new IAEA initiatives. The regional technical cooperation (TC) programme in Europe and Central Asia aims to enhance collaboration among the Member States of the region, as well as with other partners. The document, prepared by Member States with support from the IAEA Secretariat, builds on the experience gained during 2009–2021 and is complemented by additional information available from national and regional sources.

Analysis conducted during the preparation of this iteration of the profile highlighted that the trends and priorities outlined in the previous Regional Profiles for Europe remain mostly valid. The main aim of this revision, therefore, is to update the document based on the significant progress made in the region through the implementation of the regional TC programme cycles and taking into consideration new IAEA initiatives.

The four priority thematic areas for the Member States in Europe and Central Asia participating in the IAEA TC programme (and also as identified in the TCEU Strategic Framework 2019–2025) are as follows:

i. **Nuclear and radiation safety,** including nuclear installation safety, waste and environmental safety, emergency preparedness and response, radiation protection and safe transport of radioactive materials. Nuclear security, while important for the region, is managed by the Division of Nuclear Security and thus is not included in this Profile which facilitates the preparation of future regional TC programmes.

ii. **Nuclear energy,** including energy planning and nuclear power, nuclear fuel cycle and fuel technology, waste and spent fuel management, decommissioning, environmental remediation, and nuclear sciences.

iii. **Human health,** including nuclear medicine, radiotherapy, medical imaging and medical physics.

iv. **Isotope and radiation technologies,** including environmental monitoring/ conservation, water resources assessment and management, and agricultural and industrial applications.

Photo: A portable X-ray fluorescence spectrometer helps scientists analyse a portrait of Saint George, one of Christianity's most famous saints. (Photo: IAEA)

A brief overview of the components of the above thematic areas pertaining to the current situation in Europe and Central Asia is presented below:

Nuclear and radiation safety

- Governmental, legal and regulatory framework
- Nuclear knowledge management and capacity building
- Safety culture
- Nuclear installation safety
- Emergency preparedness and response
- Public awareness
- Environmental radiation protection
- Recycling, reuse, radioactive waste management, decommissioning and remediation

Nuclear energy

- Sustainable energy development and energy policy, including climate change
- Nuclear knowledge management and human resource development
- Nuclear installation performance and engineering aspects of nuclear facilities
- Small modular reactors (SMRs)
- Nuclear fuel cycle
- Research reactors

Human health

- Improving quality of all radiation medicine services
- Capacity building for health professionals in radiation medicine
- Strengthening infrastructure and supporting introduction of advanced technologies in radiation medicine

Isotope and radiation technology applications

- Use of isotopes and ionizing radiation
- Environment monitoring and preservation
- Water resources management and isotope hydrology
- Advanced materials

The above list is an indication only, and does not exclude consideration of new areas of cooperation that could arise. It is acknowledged that the four priority thematic areas include cross-cutting issues, and that future regional projects can have more than one thematic area. The Regional Profile for Europe and Central Asia guides and complements the ongoing consultative process between Member States and the Secretariat in identifying possible areas of cooperation.

Introduction

Regional projects constitute a key feature of the IAEA's technical cooperation (TC) programme. These projects deliver support to address transboundary issues and regional needs. Regional project activities consist of workshops, meetings, training courses, group scientific visits and fellowships, as well as the provision of equipment and expert services that would enhance national infrastructure and harmonize capabilities among participating Member States.

It is possible to address the challenges of smaller groups of Member States in Europe and Central Asia through a sub-regional approach.

All Members States in the region are eligible for support.

Even though most of the participating countries have a national programme, there are a number that participate only in the regional programme. Furthermore, some countries receiving minor support from the TC programme are supporting other countries by providing expertise and extra budgetary resources.

The Regional Profile for 2022–2027 was jointly prepared by the Member States and the IAEA Secretariat. It is an update of the previous Regional Profiles (for 2009–2013, 2014–2017, 2018–2021) and takes into consideration the current situation and emerging trends, as well as relevant additional and new data available from national and regional sources. The Regional Profile guides and complements the ongoing consultative process between Member States and the Secretariat, which is aimed at identifying possible areas of cooperation.

This Regional Profile recognizes the ability of all suitably qualified individuals, regardless of gender, to equally contribute to and benefit from the TC programme and encourages gender mainstreaming in all programmatic activities.

The following countries currently participate in IAEA's technical cooperation programme:

Albania
Armenia
Azerbaijan
Belarus
Bosnia and Herzegovina
Bulgaria
Croatia
Cyprus
Czech Republic
Estonia
Georgia
Greece
Hungary
Kazakhstan
Kyrgyzstan
Latvia
Lithuania
Malta
Montenegro
Poland
Portugal
Republic of Moldova
Romania
Russian Federation
Serbia
Slovakia
Slovenia
Republic of Tajikistan
The Republic of North Macedonia
Türkiye
Turkmenistan
Ukraine
Uzbekistan

The BN-800 commercial fast reactor at the Beloyarsk Nuclear Power Plant in Russia. (Photo: Rosenergoatom)

Situation analysis

The situation analysis has identified the following main features and trends in Europe and Central Asia. These should be taken into account during the planning of the next regional programmes:

- there is a wide diversity of Member States in the region – with different levels of socioeconomic development, and a wide range of different applications of nuclear energy and radiation sources;
- most Member States in Europe and Central Asia already have functional governmental, legislative and regulatory infrastructure. Ten of the Member States receiving TC assistance in the region are already operating nuclear power plants. In addition, five countries are currently considering or actively embarking on a nuclear power programme with their first nuclear power plant. Over ten countries operate research reactors[1];
- fifteen of the recipient Member States in Europe and Central Asia are members of the European Union (EU) and five additional Member States are EU candidate countries[2];
- most Member States are contracting parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, Convention on Nuclear Safety, and Convention on the Physical Protection of Nuclear Material and its Amendment;
- several of the Member States in the region have uranium legacy mining sites which require site characterization and remediation;
- the demand for a safe, economical, secure and reliable energy supply is increasing, options for addressing this demand may include nuclear power;
- radioactive waste and spent fuel management, including reprocessing, storage and disposal possibilities, are important considerations that need to be planned and provided for as part of the development of nuclear power;
- most Member States in the region are facing challenges in regulating residues arising from activities involving naturally occurring radioactive material (NORM);
- the consequences of the Chornobyl accident still represent a challenge for some areas of the region;
- service life extension and re-extension and power up-rate of operating nuclear power plants (NPPs) have been decided upon and in some cases implemented;
- there is a constant need for knowledge management of personnel to strengthen and ensure nuclear and radiation safety;
- effective international cooperation and dialogue is important in strengthening and ensuring nuclear and radiation safety in the region;
- since all Member States use sources of ionizing radiation for medical applications, the protection of patients along with the occupational and public protection needs further emphasis;
- qualified professionals trained in modern radiation medicine techniques are needed in Europe and Central Asia to satisfy the staffing requirements of medical centres, to ensure safe use of equipment and to achieve and maintain the quality of health services;
- there is a clear demand to further promote self-reliance in planning and implementing hydrological studies and projects incorporating the use of isotope hydrology tools, as well as to build up and/or to consolidate laboratory capacities.

1 As of 29 September 2022

2 As of 29 September 2022

Technical cooperation is an important and efficient mechanism for increasing competencies in Member States and ensuring effective and open exchange of experience and practice among them in all areas related to the peaceful use of nuclear energy. In particular, there is a renewed interest in the fields of nuclear power and its role in climate change mitigation. Member States have also stressed the importance of extending the lifetime of existing NPPs and nuclear fuel cycle facilities, as well as the construction of new NPP units and fuel cycle facilities in the region.

Activities under the TC regional programme focus on maintaining a sufficient number of well-trained personnel, and on building the capacity of young specialists to enhance the capabilities of involved parties.

Nuclear and radiation safety

Governmental, legal and regulatory framework

In some countries in Europe and Central Asia, the regulatory infrastructure for nuclear and radiation safety is not yet fully developed. Several countries are in the process of updating their legislation with the aim of completing regulatory independence.

In addition, as new generation reactor technologies, including small modular reactors, are introduced, relevant nuclear regulatory frameworks are needed.

In some countries in the region, legislation related to medical exposure (patients, carers and comforters and volunteers in biomedical research programmes) requires further improvement to align it with the IAEA Safety Standards.

Member States in the region have established the legal and regulatory framework for the safe transport of radioactive materials, and are making efforts to strengthen and improve it in line with the IAEA Safety Standards.

Nuclear knowledge management and capacity building

Socioeconomic changes in Europe and Central Asia during the last few decades have brought new challenges to nuclear institutions and facilities with radiation sources. Member States need to strengthen their capacities to establish, manage and use their nuclear knowledge management databases by developing knowledge management methodologies, guidance and tools. In addition, the training of regulators and operators needs to keep pace with advances in nuclear technology. In order to support the Member States' efforts towards transformation and institutional development, support is needed on a regional basis.

It is important to strengthen regional capabilities for preserving and transferring nuclear knowledge in a wide range of applications. Strengthening mechanisms to collect, maintain and disseminate knowledge is necessary to develop — through e-learning and other innovative educational technologies — the new skills and competencies necessary to ensure nuclear and radiation safety culture in all fields. Qualified staff are key for the development of an adequate national regulatory infrastructure.

Due to long periods when only a few nuclear facilities were built, interest in nuclear education has decreased in the region, and, with the ageing of the workforce and the retirement of qualified personnel, there is a lack of newly qualified personnel in the nuclear power area. The need for decommissioning of the nuclear facilities should be considered as well.

Constant new developments in the use of radiation sources in fields like medicine and industry mean that there is a continuous need for sufficient competent, qualified personnel within the regulatory bodies.

Nuclear and radiation safety requires qualified personnel as well. However, these needs in a

State-of-the-art technology used to produce radiopharmaceuticals developed with IAEA support. (Photo: IAEA)

Member State are not often enough to support sustainable national teaching programmes.

Safety culture

The promotion of leadership and management for safety needs to be taken into account in national policies and strategies for safety.

The regulatory bodies for safety need to foster and support a safety culture through the development and reinforcement of leadership in their own organizations, but also to promote and include in their regulatory inspections safety culture within authorized parties.

Safety assessment is an integral part of all main decisions on nuclear and radiation safety. There is a continuous need to maintain and strengthen the relevant safety culture. Member States have necessary technical knowledge and best practices to share in order to enhance safety culture.

Member States need to undertake relevant actions to improve the safety culture in regulatory bodies and operators to increase their level of awareness of their responsibilities.

Member States need to pay sufficient attention to workplace monitoring, especially when considering the internal exposure of workers.

Nuclear installation safety

The lessons and observations from the Fukushima Daiichi nuclear accident led to recommendations for the reinforcement of the Defense in Depth concept for the design of nuclear installations in general, and particularly for nuclear power plants. Member States are implementing the design modifications to meet the stress test requirements and safety recommendations based on the lessons learnt and observations from the Fukushima Daiichi accident. Relevant operational experience and lessons learnt from before the Fukushima accident, as well as from later incidents, also need due consideration.

Emergency preparedness and response

Member States have implemented measures to improve existing preparedness and response arrangements to nuclear and/or radiological emergencies, including after the Fukushima accident. The main challenges identified are the enhancement of those arrangements for dealing with accidents, approaches and methods of source term estimation, development of procedures and joint actions by various governmental agencies, and improvements in international cooperation and initiatives in the different emergency preparedness and response (EPR) areas.

Member States in Europe and Central Asia continue improving their national frameworks for preparedness and response to nuclear and/or radiological emergencies in line with the IAEA Safety Standards[3].

Public awareness

Member States recognize that raising public awareness and knowledge about nuclear energy technology and its applications is a crucial component for decision-making and for the sustainable and safe use of nuclear technology.

Member States recognize the need for the regulatory bodies and operators to promote the establishment of appropriate means of consulting interested parties and informing the public about the possible radiation risks associated with facilities and activities, including their actual level of safety as well as the radiation data of the environment actually measured, together with the measures taken to reduce and mitigate them, in order to enhance confidence in the application of nuclear science and technology and strengthen communication among key stakeholders.

IAEA nuclear safety experts conduct radiological measurements at the Exclusion Zone surrounding the Chornobyl Nuclear Power Plant in Ukraine. (Photo: IAEA)

Environmental radiation protection

Regulatory frameworks have been established in many countries to enhance environmental radiation protection. Additional activities need to be implemented and human resources developed in order to achieve compliance with national or international standards.

Recycling, reuse, radioactive waste management, decommissioning and remediation

The majority of Member States have become contracting parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, and undertake relevant measures to fulfil their obligations. There are countries that put efforts into establishing policies on pre-disposal management, radioactive waste storage and decommissioning, as well as putting in place the associated arrangements to fully implement those policies. There are countries with disposal options for radioactive waste. However, there is also a remarkable number of countries that do not have any disposal options available.

In Member States, radioactive waste is collected and stored at centralized facilities or on-site. However, capabilities to treat this

3 As of the end of 2021, twenty-four Member States from the Europe and Central Asia region provided information and conducted self-assessments in the Emergency Preparedness and Response Information Management System (EPRIMS). Of these, ten Member States have indicated that they fully or almost fully met the safety requirements in the area of EPR.

waste are often limited, especially to minimize the amount of waste for future treatments, including disposal. There are countries in the region, which have a legacy of radioactive contamination.

Some Member States in the region require some improvement to their radioactive waste management, including the development of human resources.

Many countries undertake measures to perform comprehensive assessments of chronic exposure and to apply the concept of clearance of radioactive material, consistent with the IAEA Safety Standards during the implementation of radioactive waste management activities. These measures are also being applied to legacy uranium mine sites in many of the countries in the region.

There is a need to prioritize the facilitation of the safe reuse and recycling of materials resulting from nuclear activities, including spent nuclear fuel reprocessing, in order to mitigate the impact on the environment and increase public awareness and acceptance based on the principle of conservation of natural raw resources (also taking into consideration the capacity of repositories).

Decommissioning activities are being implemented in several countries, including planning, physical and radiological characterization, facility and site decontamination, dismantling and materials management.

Some Member States are in the process of establishing regulatory frameworks relative to naturally occurring radioactive material (NORM), using a graded approach.

Nuclear energy

Sustainable energy development and energy policy, including climate change

There is a strong need to increase the contribution of low pollution and low Greenhouse Gas emission sources of energy such as nuclear power and renewable sources in the future.

To provide energy security, it is important to diversify the sources of energy supply.

Nuclear power plays and will continue to play an important role in the socioeconomic development of the region. Planning tools should help countries answer questions on how to decarbonize the energy system in line with the Paris Agreement, how new NPPs might fit into long-term development plans, and how NPPs can compete in the electricity market.

Member States that have decided on the introduction of nuclear power require guidance and support to establish the necessary infrastructure.

Hydrogen has the potential to play an important role as a sustainable and environmentally acceptable source of energy in the region. However, there are technical challenges in nuclear hydrogen processes, which need to be addressed through comprehensive research and development efforts.

Nuclear Power Plant, Ukraine. (Photo: Rivne NPP)

Training exercise at Dukovany NPP, Czech Republic. (Photo: Dean Calma/IAEA)

Nuclear knowledge management and human resource development

The Fukushima accident highlighted the need for well-trained NPP personnel. Training and refresher courses are essential, particularly when state-of-the-art science and technology is to be implemented. Correspondingly, the necessary engineering and technical support in all related fields (e.g. engineers, chemists, metallurgists, physicists, geologists, and radiologists) should be available throughout the lifetime of a nuclear installation (from design to decommissioning). Thus, access to higher education and the availability of appropriate curricula at universities should be promoted for the future operation of NPPs.

Developing and launching nuclear programmes, both for electricity generation and non-electrical energy applications, requires the development of adequate scientific and engineering capabilities. The region has an excellent history in nuclear science and engineering and a well-developed network of research and engineering institutions.

Nuclear installation performance and engineering aspects of nuclear facilities

The operational safety of nuclear installations in Europe and Central Asia is being improved continuously. Sharing experience and knowledge within and among the regulators is a valuable means of improving safety and safety culture. It is important to disseminate lessons learned to improve the design, operation and maintenance of nuclear installations. Openness and transparency in operation and regulatory practices are also essential to enhance public confidence.

Following the Fukushima accident, the stress tests (safety assessments) which were carried out in the region alongside routine regulatory body activities have resulted in several recommendations aimed at further improving nuclear safety. Most of the recommendations have been implemented.

Most reactors operating in the region are intended for long-term operation. Some reactor operators have already applied for an extended operation license or are in the process of service life extension and re-extension. It is important that the regulators and operators in the region have a clear and coordinated approach to plant specific (periodic) safety assessments, for critical systems, structures and components. Power up-rates have been implemented in several countries, but remain a challenge for the region. Due to delays with the construction of new NPPs, a number of expanding countries are implementing measures for lifetime extension and require expert and advisory support from the IAEA.

As more than two-thirds of nuclear fuel cycle facilities are older than thirty years, there is a need to refurbish, modernize and upgrade these facilities to allow for operation beyond their anticipated design life. It is important that the regulators and operators in the region adhere to a coordinated approach, based on best practices for a sustainable approach to identifying and predicting risks associated with the ageing of structures and components, methodology for choosing an obsolescence risk management strategy, maintenance strategies, inspections and tests, record-keeping, and strategies for continuous improvement of nuclear fuel cycle facilities.

Small modular reactors (SMRs)

Regional interest in small and medium sized or modular reactors has been increasing due to their potential ability to meet the need for flexible power generation for a wider range of users and applications and to replace ageing fossil fuel-fired power plants. SMRs also display an enhanced safety performance through inherent and passive safety features, offer better upfront capital cost affordability and are suitable for cogeneration and non-electric applications. In addition, they offer options for remote regions with less developed infrastructures and the possibility for synergetic hybrid energy systems that combine nuclear and alternate energy sources, including renewables. SMRs are therefore an option to fulfil the need for flexible power generation for a wider range of users and applications in the region. Many Member States are considering the development and/or deployment of these facilities.

Nuclear fuel cycle

As part of the nuclear fuel cycle, uranium mining and processing requires effective decommissioning and remediation of facilities and sites at the end of their life cycle. Many of the countries in the region have abandoned legacy uranium mines and associated processing facilities that require effective site characterization and the subsequent development of remediation plans to ensure the safety of the public and the environment around these legacy sites.

Nuclear fuel design and production is continuously enhanced over the years through the design of improvements to fuel assemblies and the fabrication process (automation and digitization, reduced operational waste, improved radiation protection for workers, reducing fuel failures in the reactors)[4].

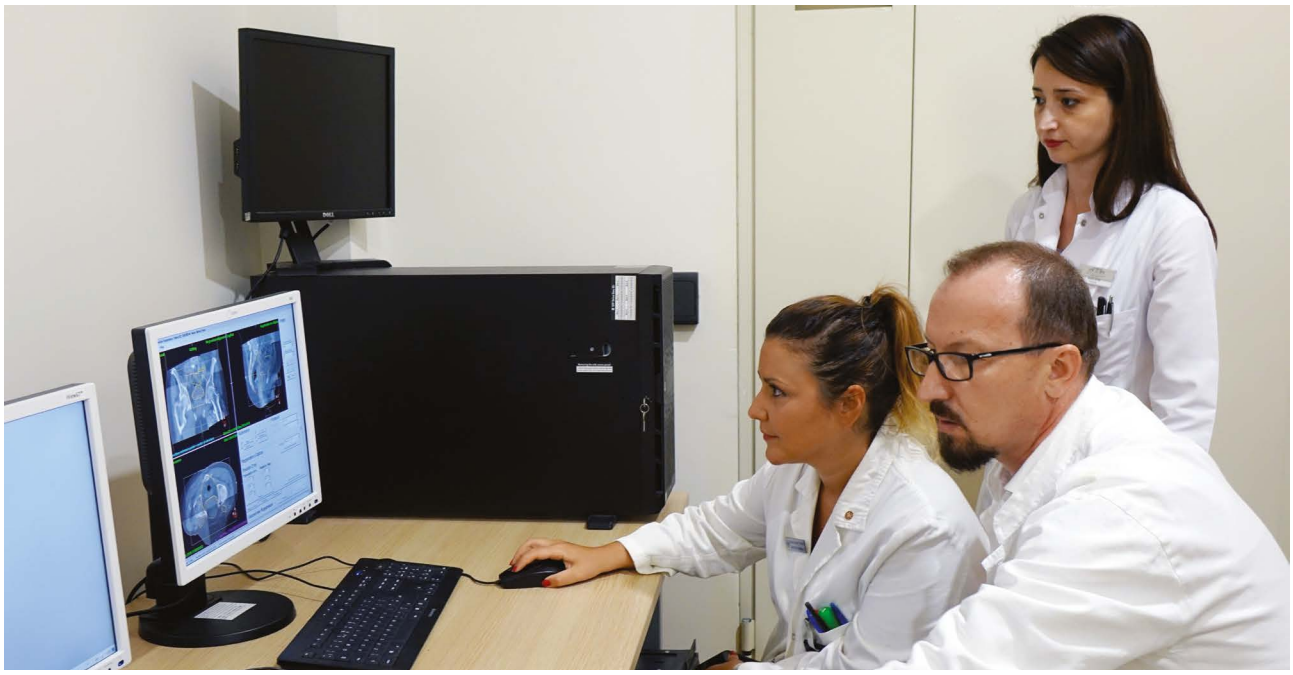
Advanced approaches to spent fuel management, including reprocessing, are being considered by several countries.

Member States in Europe and Central Asia face a growing number of responsibilities regarding decommissioning nuclear facilities, ranging from research reactors to nuclear power plants reaching the end of their operating life.

Environmental remediation at specific sites, including several legacy sites, needs to be planned and provided for, and effective environmental management approaches shared in the region.

Member States in the region have a very broad range in the scale and diversity of waste management responsibilities that needs to be addressed.

4 Efforts have focused on improvements to the safety of fuels used in existing large scale Light Water Reactor (LWR) fleets with different designs of Accident Tolerant Fuels (ATF); nuclear fuel development for the innovative reactors like Generation IV (Gen-IV) and SMR (ranging from scaled down versions of LWR fuel designs to entirely new Gen-IV designs); improvement of economics and sustainability with elongation of fuel cycles, higher burnup, zero defect campaigns, multiple recycling of nuclear materials from Spent Nuclear Fuel (SNF) reprocessing, new fuel cycle, innovative methods for fuel manufacturing. High assay low-enriched uranium (HALEU) is required for many innovative nuclear fuel concepts like SMR or ATF.



Medical physicists and radiation therapists work together to assure treatment is given accurately and correctly at the University Medical Centre 'Mother Teresa', Tirana, Albania. (Photo: IAEA)

Waste disposal requires specific attention to ensure comprehensive and realistic plans are developed, including first steps to establish disposal facilities.

Research reactors

There are many research reactors in the region, some requiring IAEA support for efficient utilization or refurbishing.

Human health

Improving quality of all radiation medicine services

With the installation of new equipment and the implementation of modern treatment and diagnostics modalities for radiation medicine in the region, together with appropriate training of medical radiological practitioners, more patients have access to better diagnosis, and receive more effective treatment with higher survival rates and fewer treatment side effects. Nevertheless, qualified professionals trained in modern radiation medicine techniques are needed in Europe and Central Asia to satisfy the staffing requirements of medical centres, to ensure the safe use of equipment, and to achieve and maintain the quality of health services.

Radiotherapy is an indispensable component in the treatment of cancer patients and is considered appropriate for more than 50% of cases. However, within Europe and Central Asia, there are vast discrepancies in the availability of facilities to provide radiotherapy in compliance with internationally accepted standards.

Technology for nuclear medicine and diagnostic imaging radiology has been available in many countries for some years, but there is still a need for further application of the technology in some Member States.

Furthermore, there is an increasing demand to establish clinical radiopharmacy, including applications for theranostics.

The majority of countries have undertaken measures to comply with the regulatory requirements in diagnostic radiology, nuclear medicine and radiotherapy.

The majority of Member States have established procedures to prevent unintended

and accidental medical exposures of patients and for reporting significant events to the regulatory authority. Further efforts will be needed to improve safety culture and incident reporting in the medical facilities, in order to learn from incidents and improve patient safety.

Quality and safety management in medical procedures continues to be a priority in the region.

Member States in the region are making efforts to combat cancer including through projects under the RoH initiative and to build or strengthen their capacities to prepare for and respond to threats and outbreaks of zoonotic diseases/pandemic including through the Zoonotic Disease Integrated Action (ZODIAC) projects.

Capacity building for health professionals in radiation medicine

Many Member States in the region have strengthened their capacities for the early detection, diagnosis and treatment of oncological diseases through the application of diagnostic radiology, nuclear medicine technologies and radiotherapy services, supported by the IAEA TC programme.

IAEA has been providing support for the establishment and strengthening of nuclear medicine, diagnostic radiology imaging and radiotherapy services, providing education and training of health professionals.

Counterpart showing how exposure to radiation affects the structure of the chromosomes in the human cell in Kurchatov, Kazakhstan. (Photo: Alexey Katukhov/IAEA)

However, the technologies are advancing fast, and there is a strong need to provide education and continuous training, and to build human resource capacity to ensure quality and safety in the use of these new technologies, as well as to raise awareness of the importance of quality management in radiation medicine services.

Furthermore, education and training programmes for health professionals, in particular for Medical Physicists and Medical Radiation Technologists, in all three areas of radiation medicine have to be established and harmonized to set the minimum requirements in Member States of the region.

Strengthening infrastructure and supporting introduction of advanced technologies in radiation medicine

Many countries in the region have established national cancer control programmes, and are putting efforts into improving their infrastructure, installing cutting-edge technologies and making more effective use of limited human resources.

Medical facilities in several countries and centres of the region operate in compliance with internationally acceptable standards, but others may still need significant support. There is a common interest in applying new diagnostic and treatment techniques, e.g. intensity modulated radiation therapy (IMRT) and image guided radiation therapy (IGRT) in radiotherapy, in combination with image fusion (CT/ magnetic resonance imaging (MRI), SPECT/CT, PET/CT) and hadron therapy for better diagnosis and treatment.

While advanced technology is mainly associated with external beam radiotherapy, effective treatment of cervical cancer requires the use of brachytherapy. Several countries and centres in the region still lack brachytherapy services and modern equipment.

The use of modern technologies in nuclear medicine and diagnostic and interventional radiology is increasing in the region. Some

The IAEA is supporting experts from Heritage Malta to use x-ray technology to understand and preserve valuable ancient artefacts without damaging them. (Photo: Katy Laffan/IAEA)

countries have made significant efforts to ensure quality and safety in these areas, including the greater involvement of medical physicists in clinical practice. Other countries still need extensive and continuous support. The introduction of new techniques in nuclear medicine, diagnostic radiology and radiotherapy requires independent verification of quality, and many medical facilities in the countries of the region participate in various types of audits before the new technology is implemented, including those offered by the IAEA (see IAEA Services Review).

Isotope and radiation technology applications

Use of isotopes and ionizing radiation

The use of radioisotopes significantly contributes to the improvement of health care in most countries, therefore the production of radiopharmaceuticals from radiological/nuclear installations and cyclotrons/nuclear research reactors is a growing priority in the region.

Nucleonic control systems, recognized as the most requested of the radioisotope techniques for measurement and analysis, are widely used in industry to improve product quality, optimize processes and save energy and materials.

Radiation sterilization by the application of accelerators, gamma sources and electron beam or X-ray systems is widely used to sterilize disposable health care products in several countries. Some countries in the region possess large accelerators or gamma-based facilities, others have built or plan to build pilot or commercial facilities. Further development of the technology depends on the availability of suitable radiation sources and on the implementation of management systems.

In some parts of the region, the sterile insect technique (SIT) is used to improve food safety and production and to reduce pesticide usage.

Some Member States have established research laboratories implementing plant mutation through the application of radiation. Potential exists for greater use of the technology and for achieving better mutant varieties.

Nuclear technology is used to quickly diagnose animal diseases that have the potential to spread from animals to animals and from animals to people. Many veterinary laboratories require capacity development and equipment to apply such technology.

The preservation of cultural heritage using nuclear applications is important for Europe

and Central Asia. Nuclear analytical methods (neutron activation analysis, X-ray fluorescence, etc.) play an important role in object identification (painting, sculpture etc.) and in the selection of preservation methods. In addition, radiation technology can be directly used for the preservation of some types of cultural heritage artefacts.

Environment monitoring and preservation

Contamination of water and the environment by industrial waste including plastic pollution and other anthropogenic activities is also a serious problem in many countries. Because of the increasing level and complexity of polluted effluents from urban areas and industry, the development and implementation of new nuclear technologies for purification are needed. Radiation processing is among the possible treatment options.

Fossil fuels are the primary energy sources in many countries in the region. They are a source of environmental pollution and thereby a transboundary issue. Among the various technologies available today, electron beam flue gas treatment technology, based on the application of accelerators, has been used in the region. For air pollution monitoring, systems based on beta-ray attenuation are being adopted. Stable isotopes ratio analyses allow the monitoring of greenhouse gases, carbon sources and sinks, and acidic pollutants. Regional cooperation in this context has a real benefit.

The region also faces challenges in the agricultural sector, in particular with land degradation and soil erosion, among other problems. Nuclear applications are used to address these challenges.

Water resources management and isotope hydrology

Ensuring a good quality water supply for human consumption, industry and agriculture is becoming increasingly difficult due to the impacts of land use and climate change, population growth, increasing industrialization and water overexploitation. Isotope hydrology techniques are an important tool for the improved assessment and management of water resources, as well as for the characterization of climate change impacts and the assessment of anthropogenic pollution on water quality and water availability.

The IAEA supports the establishment and strengthening of isotope hydrology laboratories in its Member States. The further development of these laboratories must meet the demand for isotopic data as part of the hydrological assessment, and must ensure their adequate performance in terms of Quality Assurance and Quality Control (QA/QC) of the generated data.

Advanced materials

Micro- and nanotechnologies have been developed in many Member States. Their application in areas such as materials, medicine, agriculture and the environment calls for regional cooperation.

New developments in the field of nanomaterials, related to the mechanical and physical properties of materials, may have far reaching impact, e.g. on nuclear reactor engineering.

Oko transboundary aquifer, shared between Bosnia and Herzegovina and Montenegro, near Trebinje town, during sampling for stable isotopes analyses and field parameters measurement. (Photo: Andrijana Stevanović)

Envisioned programme outline

Nuclear and radiation safety

Governmental, legal and regulatory framework

It is important to formalize procedures to ensure the consistent application of nuclear and radiation safety procedures. Comprehensive staffing plans and training programmes are needed to maintain the sustainability of the achievements made by the regulatory bodies established in the Member States.

Future regional cooperation will further align and harmonize the application of regulations with international standards and directives. It may also result in enhanced dissemination of new results stemming from other IAEA programmes and initiatives, such as, for example, the new Nuclear Harmonization and Standardization Initiative (NHSI).

Nuclear knowledge management and capacity building

Several Member States in the Europe and Central Asia Region have educational and training programmes in the fields of nuclear and radiation safety, nuclear energy, human health and isotope and radiation technology applications. However, these are not homogenous across the region. Strengthening and expanding existing methods for providing training to Member State professionals remains a priority for the region. Sub-regional and national multidisciplinary, thematic, or site-specific training courses with experienced trainers are needed. E-learning and webinars may also be applicable.

The 'Train the Trainers' approach and sub-regional collaboration may be considered for Member States lacking national capacities that require support for establishing sustainable educational and training programmes. The establishment of national strategies on education and training in radiation, transport and waste safety will facilitate the identification of education and training needs to design the most appropriate education and training programmes. This will build competence over time and optimize the use of national and IAEA resources.

Radiation protection can be enhanced by organizing regional training courses such as the Postgraduate Education Course (PGEC).

Networking in a broad sense has been recognized as an important tool to sustain development in nuclear and radiation safety, for both regulatory and industry staff. This work needs to be strengthened.

The most effective regional cooperation tool is the utilization of regional experience and the exchange of information on good practices. In addition, it is important to encourage networking, new partnerships and the sharing of experience between research institutions, technical support facilities and other organizations. Knowledge management is an integral part of public management and business operations and remains relevant to Europe and Central Asia.

Safety culture

Further efforts should be put into ensuring discipline and a high level of safety culture among operators, regulators and authorized parties.

Nuclear installation safety

Nuclear installation safety encompasses design safety and safety assessment. The periodic safety reviews conducted by the operators in Member States allow for the reassessment of key aspects such as site evaluation, design safety, safety assessment and operational safety.

Emergency preparedness and response

Member States continue to require further support to better apply the safety requirements in the IAEA Safety Standards in the area of emergency preparedness and response at the national level. This includes managing the medical response, keeping the public informed, taking longer-term protective actions,

training to respond to nuclear and radiological emergencies, and transboundary cooperation.

Topics that need to be addressed using a regional approach include protection strategy and hazard assessment, termination of the emergency, development or revision of national regulations for emergency preparedness and response, and improvement of national emergency plans and procedures in line with the IAEA Safety Standards.

Public awareness

Cooperation among Member States should be enhanced to raise public awareness about the peaceful application of nuclear and radiation technology, as well as exposures due to commodities, radon and consumer products as well as principles of radiation protection. Public awareness and information on nuclear and radiation safety and regulatory decisions should also be enhanced.

Environmental radiation protection

Member States have agreed that the use of ionizing radiation in medicine, energy production, industry and research brings enormous benefits to the public. However, potential radiation risks must be controlled and assessed. Further cooperation on environmental radiation protection issues among the Member States and IAEA under the TC programme is needed.

The impacts of anthropogenic and natural radioactivity on the environment and human health require the implementation of adequate monitoring to ensure radiation protection.

The development of air, soil and water pollution control using nuclear technologies is an important priority.

Management of NORM and reduction of public exposure to indoor radon remain a priority for the region.

Recycling, reuse, radioactive waste management, decommissioning and remediation

The priority areas in Europe and Central Asia are recycling, reuse of spent nuclear fuel, waste minimization, management of radioactive waste, international aspects of waste management and decommissioning. In order to find common solutions and approaches to similar problems, discussions should be held at the international level.

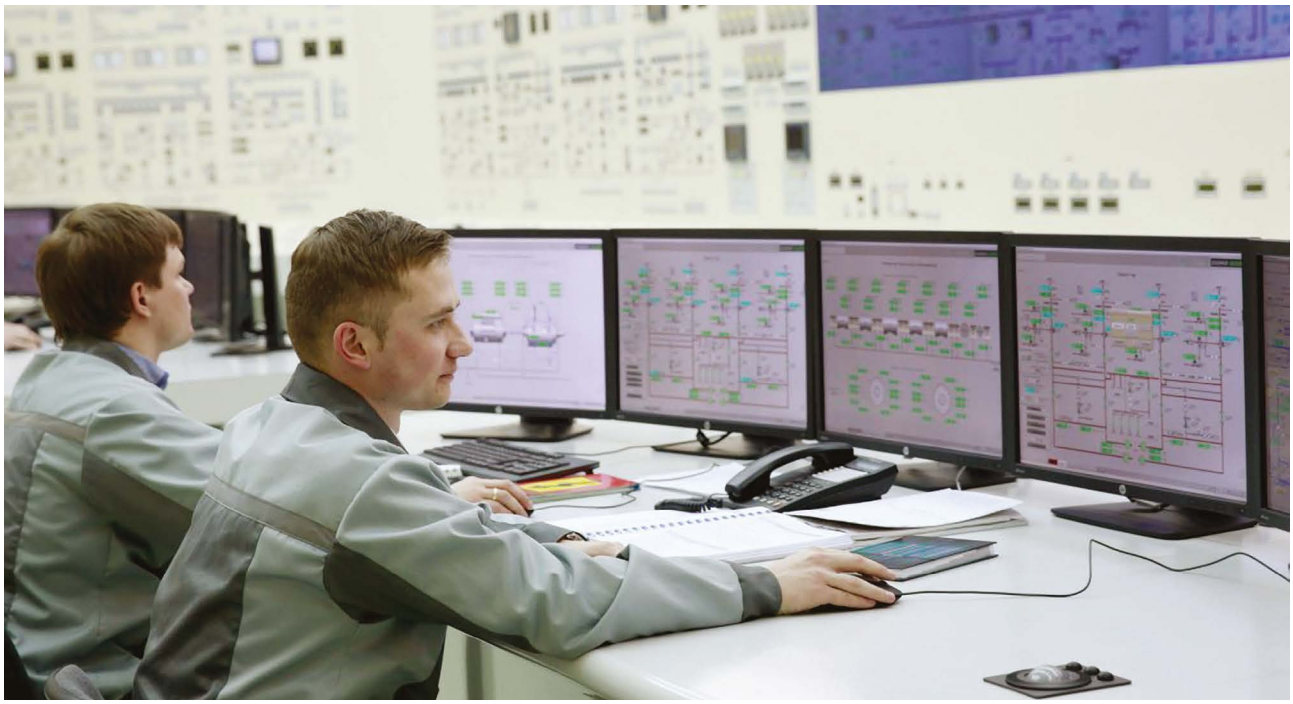
Safe management of spent nuclear fuel and radioactive waste and decommissioning activities, including those from legacy uranium mine sites, require the establishment of an adequate legal, governmental and regulatory infrastructure, including licensing for decommissioning. Capacity building in this field is essential for the region.

Ongoing efforts are being deployed to support environmental remediation to reduce radiation exposure from contaminated land areas or other contaminated media, such as surface or groundwater, in the region. In addition, particular attention within the context of environmental monitoring activities should still be paid to the Chornobyl situation.

Nuclear energy

Sustainable energy development and energy policy including climate change

All aspects related to the planning, development and introduction of a nuclear power programme, as well as the elaboration of research projects related to nuclear power and technology, are important in the region. It is necessary to distribute, among interested countries, tools for planning and establishing the required infrastructure for the introduction of nuclear power programmes in the new economic environment, as well as to share experiences gained from feasibility studies carried out in the region. The regional aspects



Workers of the Belarusian nuclear power plant practice at the full-scale simulator of plant's power generating unit at the training center near the town of Ostrovets. (Photo: Ostrovets NPP Press Office)

of nuclear power planning are also important, taking into account the tendency towards the integration of national electrical power networks in the region.

Launching and extending nuclear power programmes requires the development and maintenance of engineering capabilities in site selection, design, evaluation and modernization of nuclear installations. Recent extreme natural events (tsunamis, storm surges, hurricanes and earthquakes) have called for a detailed review of siting and design of nuclear installations, reflected in risk assessment reports.

Nuclear power is a low-carbon source of energy. Together with expanding renewable energy sources and fuel switching from coal to gas, higher nuclear power production contributes to a reduction in global CO_2 emissions. Nuclear power – as a dispatchable low carbon source of electricity – can play a key role in the transition to a clean energy future. As part of the capacity building process for technology-neutral energy systems analysis and planning, IAEA assistance to Member States through the technical cooperation programme will include decarbonization pathways in line with the Paris Agreement, e.g., to inform the development of Nationally Determined Contributions and related national energy and climate plans and strategies. This includes assessing the role of nuclear energy within these decarbonization pathways for those participating Member States considering this option.

The IAEA, through the TC programme, implements regional projects aimed at contributing to the diversification, harmonization and safe development of 'low-carbon' energy mixes, including hydrogen.

Nuclear knowledge management and human resource development

It is now widely accepted that leadership and management of safety have a profound influence on the safe performance of nuclear installations, and that they are essential in developing a strong nuclear safety culture. The promotion of safety culture and high levels

of harmonized nuclear safety practices is an important direction for regional cooperation.

Assistance to Member States in effective licensing and oversight processes for nuclear power plant new designs, re-designs and technologies, construction, ageing management, plant life extensions, etc., should be continued.

Nuclear installation performance and engineering aspects of nuclear facilities

The following topics are priorities for regional cooperation: assurance and quality of services for nuclear installations; in-service inspection and maintenance, including risk informed on-site inspection and maintenance; operational feedback and exchange of experience; human factors in operation; self-assessment; modernization of instrumentation and control systems to establish digital systems; ageing/plant life management and operational data collection, processing and exchange. It is necessary to guarantee the quality of services provided through outsourcing, and to enhance the technical competence of scientists/engineers in the field of reactor core and fuel reliability.

Long term operation and power up-rating of existing reactors poses extensive engineering challenges to maintaining or enhancing the safe operation of nuclear installations. An on-going and permanent exchange of experience on methodology and the results of long term operation (LTO) of NPPs at the regional level is necessary. The development and utilization of advanced techniques in both probabilistic and deterministic safety analyses far exceeds the capabilities of many organizations and even countries. This has to be taken into account in Member States' needs. The need for implementation of periodic safety assessments is widely acknowledged. These issues would require interregional cooperation.

Small modular reactors (SMRs)

Several Member States are focusing on the technology development/deployment of SMRs and need comprehensive assistance and support from the IAEA in areas such as establishing, revising and harmonizing safety regulations and rules, and licensing.

Nuclear fuel cycle (NFC)

Priority areas are: fuel safety criteria and fuel licensing; spent fuel management (financial and safety aspects) and recycling; NFC 'back-end' for open and closed cycle; and NFC 'front-end'; effective site characterization and subsequent development of remediation plans for abandoned and legacy uranium mines and associated processing facilities to ensure safety of the public and the environment around these legacy sites. These priorities cover a wider nuclear fuel cycle range than just the technical aspects of the NFC front and back ends.

For nuclear fuel fabrication and core management, the programme will include implementing accident tolerant fuels, fuels for innovative reactors like Gen-IV reactors and SMRs, improving economics and sustainability.

The TC programme will support a harmonized understanding for planning and developing effective decommissioning projects at the end of the operating life of all types of nuclear facilities.

Effective environmental management approaches shared through the TC programme can support Member States in the region in addressing environmental remediation at specific sites, including several so-called legacy sites.

Waste disposal, in particular, requires specific attention within all Member States of the region to ensure comprehensive and realistic plans are being developed and that the first steps of implementation are being considered for the necessary disposal facilities.

Research reactors

Assistance will be provided both to institutions running these facilities and to regulatory authorities to assure safety during the remainder of the operational life of the facilities and during their decommissioning. Cooperation among countries possessing research reactors becomes increasingly important, taking into account the need to facilitate continued basic research on both materials behaviour under irradiation and on other ageing mechanisms under realistic conditions.

Human health

Improving the quality of medical services

Areas for regional cooperation in the medium term should be mainly focused on the introduction, implementation and improvement of cancer care capacity in Member States, through integrating nuclear medicine, diagnostic radiology and radiotherapy into comprehensive national cancer control programmes that will maximize diagnostic and therapeutic effectiveness.

Some Member States need to strengthen the requirements for appropriate quality management systems for diagnostic and interventional radiology, nuclear medicine and radiotherapy. Such programmes should also include calibrations for dosimetry instrumentation and medical radiological equipment, dosimetry of patients, and a well-established quality assurance programme.

Furthermore, continued support should be provided to strengthen the legislation and implementation of the IAEA Safety Standards for medical exposures.

Radiotherapy remains a major cost-effective modality for cancer treatment. Fostering and maintaining a quality assurance programme, leading to accurate dosimetry, dose delivery/optimization and patient protection is of paramount importance for the safe and successful application of the technique. Within Member States, training courses to raise awareness in this area (including courses in the Russian language) are planned, targeting sub-regions.

Member States require assistance in the development of radiotherapy centres with programmes that deliver treatments with a 3D-conformal, optimized treatment planning, using all the necessary accessories for the accurate delivery of dose. New techniques such as IMRT, image guided radiotherapy or stereotactic radiotherapy are areas for cooperation in this field.

Member States require assistance in expanding radiotherapy services towards brachytherapy to enhance the treatment of cervical cancer patients.

Technology for nuclear medicine and diagnostic imaging has significantly improved since the introduction of hybrid systems (SPECT/CT and PET/CT) and support is required for the appropriate use of these new modalities in the region, as well as for the proper use of novel radiopharmaceuticals for theranostics.

Particular attention is required for medical physicists, a health profession seldom recognized as such and crucial for radiation medicine (radiotherapy, diagnostic imaging and nuclear medicine). Member States require assistance in establishing the medical physics profession in alignment with international best practices and with IAEA standards and guidelines, taking into account relevant aspects such as education and training, recognition of the profession of medical physics, and staffing levels.

Capacity building for health professionals in radiation medicine

As technology in radiation medicine develops rapidly, health professionals should be given opportunities for continuous learning. In order to satisfy the staffing requirements of medical

facilities, most Member States in Europe and Central Asia require more training opportunities for radiation oncologists, technologists and medical physicists for radiotherapy; nuclear medicine physicians, medical physicists, radiopharmacists and technologists for nuclear medicine; and radiologists, radiographers and medical physicists in diagnostic and interventional radiology.

Member States require assistance for their efforts to provide advanced treatment modalities such as IMRT. The national radiotherapy centres that are ready to make a transition from conformal radiotherapy to IMRT will also require properly trained staff (medical physicists, radiation oncologists and radiotherapy technicians). Adequate staff training is essential prior to the initiation of such programmes.

Training of all staff involved (physicians, medical physicists, radio-pharmacists and technologists) for both hybrid imaging and therapy applications is also necessary under all circumstances.

Training for radiotherapy technologists (RTT) with hands-on experience and opportunities for collaboration with other advanced radiotherapy centres is needed, in particular through long-term scholarships for students, practical courses with hands-on experience at established and advanced radiotherapy centres, and by sending trainees for practical training, or sending trainers to a radiotherapy centre to train its entire staff.

The essential role of the medical physicist in all areas of modern radiation medicine, especially in the diagnosis of medical conditions and treatment of cancer, is still to be fostered and established.

Efforts will be made to build this profession and train more medical physicists within the TC programme. Member States require assistance for the harmonization and establishment of national educational and training programmes in medical physics, with an emphasis on clinical training.

Strengthening infrastructure and supporting the introduction of advanced technologies in radiation medicine

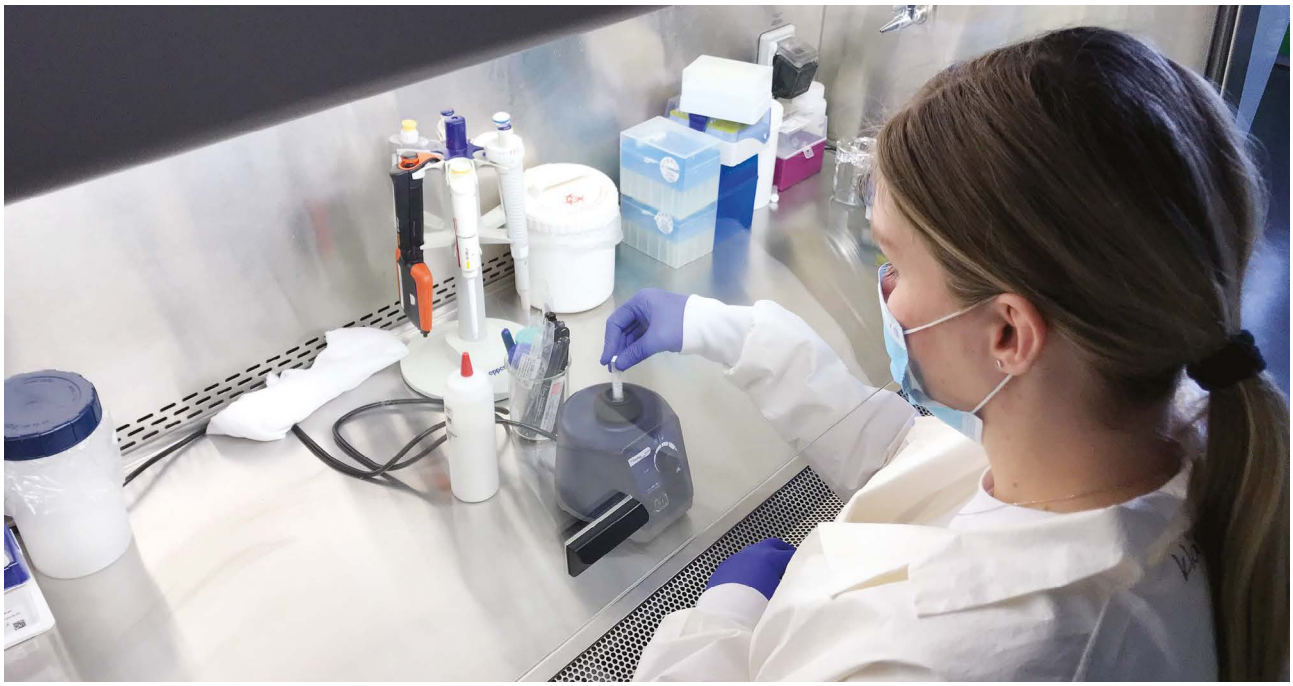
Assistance is needed for the safe introduction of advanced treatment techniques in radiotherapy, such as IMRT, IGRT, stereotactic body radiation therapy (SBRT) and 3D brachytherapy, as well as the use of advanced QA and dosimetric equipment.

Assistance related to technical and human resources is needed for the implementation of sophisticated technology in different modalities in diagnostic and interventional radiology, with the aim of improving image quality and increasing the types and number of examinations.

IAEA could assist in enhancing the sustainability of regional capacities and promoting regional self-reliance, providing a framework for sharing best practices, facilitating the introduction of new technologies and applications (supported by appropriate human resource development), harmonizing regional norms and standards, enhancing partnerships and networks, and supporting the achievement of common regional development goals.

The harmonization, distribution and adoption of available guidelines, protocols and regulations published by professional societies and various international organizations would assist clinics in Member States to elevate the quality of imaging and therapy techniques using radionuclides to internationally accepted standards.

There is a need to implement independent dosimetry audits for advanced radiotherapy techniques that are available for all medical facilities in the region.



Assistance to Czech Republic for diagnostics of COVID-19. (Photo: State Veterinary Institute Jihlava, Czech Republic)

Isotope and radiation technology applications

Use of isotopes and ionizing radiation

Management systems development and laboratory accreditation are important for continued operation and for upgrading radiation sterilization facilities. High priority should be given to these areas.

Member States use ionizing radiation in a wide range of activities such as industry and agricultural development. Harmonized protocols and standards are important in securing radiation safety.

Using nuclear techniques to quickly diagnose animal and zoonotic diseases, together with building the capacities of veterinary laboratories, is considered to be of high relevance in Europe and Central Asia. Member States are conducting joint research and strengthening their preparedness and capabilities to rapidly detect and respond in a timely fashion to outbreaks of zoonotic diseases through, inter alia, the IAEA ZODIAC project.

Reducing plastic pollution by recycling using radiation technology and conducting marine monitoring using isotopic tracing techniques are being considered by some Member States within the framework of NUclear TEChnology for Controlling Plastic Pollution (NUTEC Plastics).

Nuclear technologies are being applied to produce mutant varieties in vegetables, crops and fruits. Further assistance under the IAEA TC programme is encouraged.

Environment monitoring and preservation

Using nuclear and analytical methods to carry out environmental monitoring and the investigation of substances such as chemicals or heavy metals is a priority in many countries in Europe and Central Asia.

Water resources management and isotope hydrology

In view of the increasing demand for basic isotopic data on water, Member States will further strengthen their analytical capacities for determining the stable isotopic composition of water, including by replacing first-generation laser machines.

Quality assurance and quality control (QA/QC) and harmonization of approaches remains a major component in ensuring the reliable and efficient use of isotope data in hydrological studies.

Assistance will focus on enhancing analytical capabilities for isotope hydrology techniques.

Areas for regional cooperation will also focus on the re-enforcement of systematic isotope monitoring activities (the Global Network of Isotopes in Precipitation (GNIP), the Global Network of Isotopes in Rivers (GNIR) in collaboration between Member States and the IAEA. It is therefore recommended to continue the support provided so far to initiatives aiming to set up or expand national isotope monitoring networks for hydrology and climate.

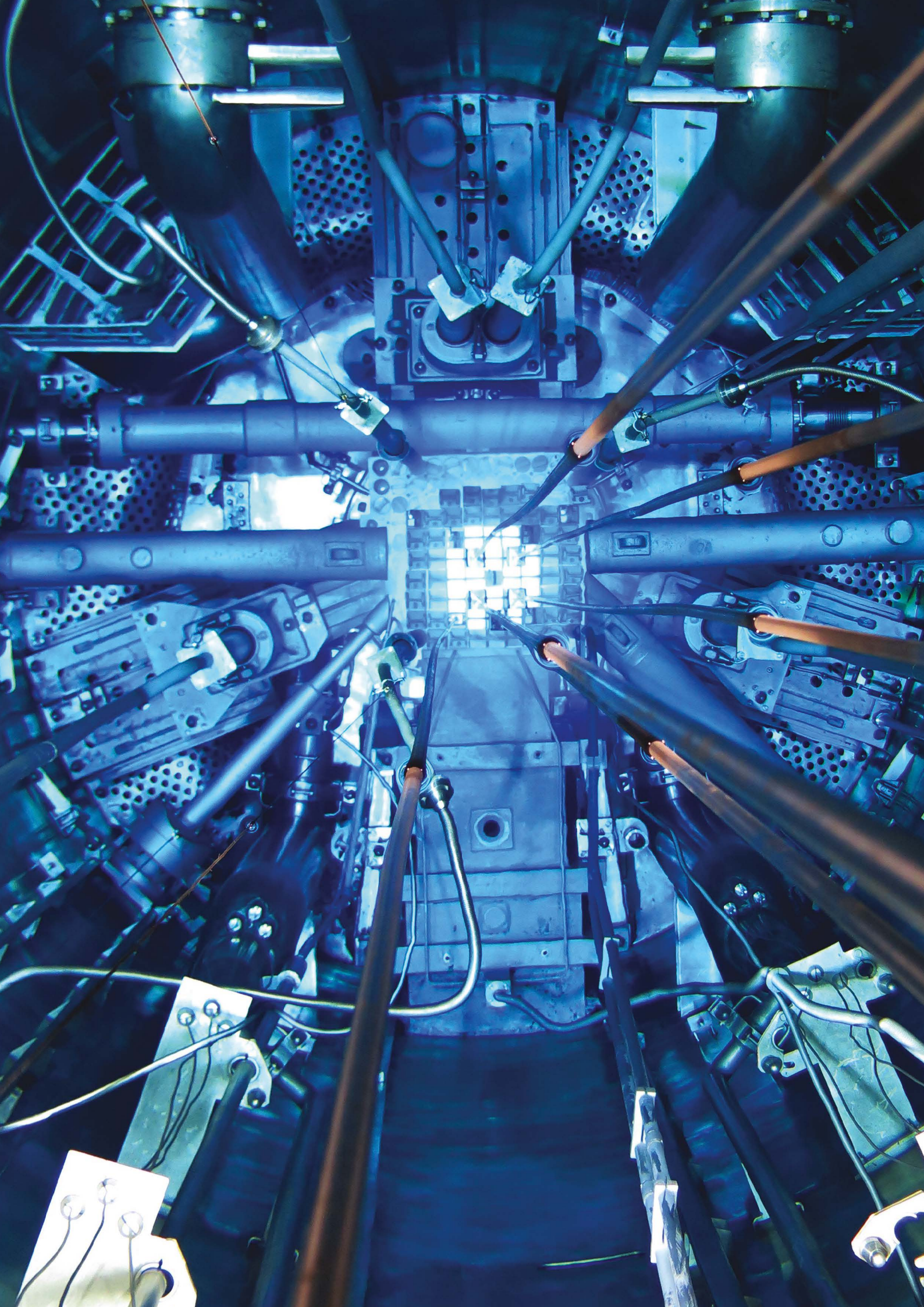
Efforts are needed to better integrate isotope studies with conventional hydrology information, which will maximize the hydrological information that can be obtained. The IAEA Water Availability Enhancement Approach (IWAVE) can help identify such synergies.

Advanced materials

Recent developments in the field of nanotechnology are likely to lead to new applications related, for example, to nuclear reactor and fuel engineering.

Nuclear technology is used to analyze materials in a wide range of areas, including biomedical research, geology and archaeological science. Accelerators can provide some of the best analytical techniques and applications. Many IAEA Member States consider accelerator-based technologies as a key element to serve social and economic development. The TC programme will continue to support Member States in their relevant activities, by training qualified staff and sharing innovative technologies.

Ice core sampling at Triglav glacier in Slovenia for isotopic analyses to determine, among others, the age of the ice. (Photo: Christoph Henrich/IAEA)



Relevant international cooperation

Nuclear and radiation safety pose a global challenge and require close international cooperation between organizations, partnerships, networks and initiatives.

Synergize all available resources with all or as many interested parties as possible in the region, and provide access to the most needed high quality training opportunities. Training programmes financed and managed by other organizations, including regional entities, will also be considered.

The IAEA plays an active part in helping the international community with the achievement of the 17 Sustainable Development Goals (SDGs), which were adopted by the Member States of the United Nations.

The IAEA works closely with other international organizations such as the World Health Organization and FAO in addressing socioeconomic needs in Europe and Central Asia.

The European Union (EU) is an important strategic partner for the IAEA. In the context of the IAEA TC programme, the EU prioritizes support for nuclear safety and security, human health, agriculture and food security, water management, climate change, environmental protection, and preservation of cultural heritage. All these areas are covered in the Regional Profile and are of high priority for Member States in the region.

The IAEA and the European Commission (EC), on behalf of Euratom, cooperate in various areas related to nuclear safety and radiation protection, as well as on life-cycle management of radioactive waste, and the decommissioning and remediation of former nuclear sites and installations.

The IAEA has been collaborating since 1997 with the European Society for Radiotherapy and Oncology (ESTRO), and since 2005 with the European Association of Nuclear Medicine (EANM), to provide specialized training opportunities to medical practitioners working in the areas of radiotherapy and nuclear medicine. The partnerships with ESTRO and EANM have played significant roles in the improvement of radiotherapy practice and the growth of nuclear medicine practice, leading to an overall improvement in radiation medicine services in Europe and Central Asia.

The IAEA should encourage and assist research and development and the practical application of atomic energy and its applications for peaceful purposes throughout the world, and foster the exchange of scientific and technical information and exchange of scientists for peaceful uses of atomic energy. The IAEA's coordinated research activities stimulate and coordinate the research activities of institutes in IAEA Member States in selected nuclear fields. Most of coordinated research activities are carried out under its Coordinated Research Projects.

Cherenkov radiation in the water that surrounds the fuel in nuclear reactors. (Photo: IAEA)

IAEA review services

The IAEA offers also several review services and missions: the IAEA Integrated Regulatory Review Service (IRRS), Integrated Safety Assessment of Research Reactors (INSARR), Safety Aspects of Long Term Operation (SALTO) Mission, Operational Safety Review Team (OSART) Mission, Quality Assurance Review Assistance Team (QARAT) Mission, Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS), Occupational Radiation Protection Appraisal Service (ORPAS), Emergency Preparedness Review Service (EPREV), Site and External Events Design Review Service (SEED) etc.[5] These

Rafael Mariano Grossi, IAEA Director General, moderated Session 1: Plastic Pollution: Challenges and the Need for Global Action, at the NUTEC Plastics Roundtable (virtual) for Europe and Central Asia held at the Agency headquarters in Vienna, Austria. (Photo: Dean Calma/IAEA)

5 A full list of IAEA Review Services can be accessed here: https://www.iaea.org/services/review-missions.

Experts from the IAEA Division of Human Health reviewing plans for the radiology department in the Kulob Oncological Hospital, Tajikistan. (Photo: Sandra Steyskal/IAEA)

services and missions can be incorporated into technical cooperation projects where appropriate on a case-by-case basis.

It is necessary to support strategic planning in radiotherapy and nuclear medicine services in individual Member States with IAEA initiatives such as Quality Assurance Team for Radiation Oncology (QUATRO) missions, Quality Management Audits in Nuclear Medicine Practices (QUANUM) and the support of IAEA programmes such as the Programme of Action for Cancer Therapy (PACT) including imPACT Review Missions. International recommendations on staffing requirements for radiotherapy centres are particularly valuable resources for Member States and could be adopted at the national level.

RASIMS is a web-based platform that enables the Member States and the IAEA Secretariat to jointly collect, analyse and view information regarding the national infrastructure for radiation and waste safety within individual countries and the region. The information is also used for the design of new technical cooperation (TC) projects and during the radiation safety clearance process prior to the provision of radiation sources. Member States continue to update profiles in RASIMS.

TCEU team at the IAEA's 66th General Conference in September 2022. (Photo: Jennifer O'Brien/IAEA)

Conclusions

The regional technical cooperation programme aims to increase the socioeconomic development of Member States by using the benefits of nuclear technology and its applications and enhancing regional collaboration in Europe and Central Asia.

A regional project provides a framework for sharing knowledge, experience and technology, for networking and cooperation among countries of a region or sub-region, and for facilitating interaction at regional level between mandated national institutions.

The Regional Profile for Europe and Central Asia guides and complements ongoing consultative processes between Member States and the Secretariat in identifying possible areas of cooperation.

The Regional Profile for Europe and Central Asia strongly encourages the creation of linkages between TC activities and the Sustainable Development Goals.

This Regional Profile for Europe and Central Asia will be reviewed and revised as deemed necessary by Member States and the IAEA.

Endorsement of the Regional Profile by National Liaison Officers on the sidelines of the IAEA's 66th General Conference in September 2022. (Photo: Jennifer O'Brien/IAEA)

Notes

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