IAEA ANNUAL REPORT 2021

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Foreword by IAEA Director General Rafael Mariano Grossi

In 2021, the COVID-19 pandemic did not let up, and nor did we. The International Atomic Energy Agency delivered its planned programmatic activity while embedding its innovative initiatives to better serve its Member States.

Our safeguards inspectors carried out more than 3000 verification activities, despite the added complications and costs of COVID-19 quarantine regulations. The Agency was able to draw soundly based conclusions for all States in which safeguards were implemented by the Agency.

In 2021, the increasingly urgent issue of climate change coupled with energy shortages in Europe and elsewhere, turned the spotlight on nuclear energy. For the first time in a decade, the Agency revised up its high-case projection of the potential growth of nuclear power capacity. In November, I led an IAEA team to COP26 to ensure nuclear energy had a seat at the highest table where energy and climate policy are discussed.

Amid the increased interest in nuclear energy, our critically important nuclear safety and security work progressed. The well-attended International Conference on a Decade of Progress After Fukushima Daiichi: Building on the Lessons Learned to Further Strengthen Nuclear Safety offered an important opportunity for high-level delegates to discuss the steadfast integration of lessons learned into today's safety culture.

While the IAEA continued to deliver its planned programmatic activity, we found new and better ways to assist Member States in building their capacities in the peaceful uses of nuclear science and technology.

NUclear TEChnology for Controlling Plastic Pollution, or NUTEC Plastics, envisages integrating nuclear techniques to address plastic recycling and marine monitoring of microplastics, and attracted much interest from Member States.

Zoonotic Disease Integrated Action received a wide reception by Member States from every continent, with some 150 of them now having designated national coordinators and more than 120 national laboratories. ZODIAC, as it is called in short, was the topic of high-level discussions at the 2021 Scientific Forum.

The Agency was fleet of foot in assisting Member States during emergencies. Through the continued delivery of RT–PCR testing equipment and the requisite knowledge, we extended the reach of our COVID-19 emergency response programme to more than 30 million people, while also offering prompt assistance following natural and industrial disasters across the world.

At home, the drive towards gender parity by 2025 led to an over 4% year-on-year increase in the number of women working within the Secretariat's professional and higher categories, which are now more gender-balanced than they have ever been.

In the following pages you will find illuminated how the IAEA delivered on its core activities while embedding its innovations into foundations that will serve it well amid the opportunities and challenges of 2022 and beyond.

Rafael Mariano Grossi
IAEA Director General

IAEA ANNUAL REPORT 2021

Article VI.J of the Agency's Statute requires the Board of Governors to submit "an annual report to the General Conference concerning the affairs of the Agency and any projects approved by the Agency".

This report covers the period 1 January to 31 December 2021.

GC(66)/4

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NEW ZEALAND
NICARAGUA
NIGER
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NORTH MACEDONIA
NORWAY
OMAN
PAKISTAN
PALAU
PANAMA
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SAN MARINO
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SRI LANKA
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SWEDEN
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SYRIAN ARAB REPUBLIC
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TRINIDAD AND TOBAGO
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TÜRKİYE*
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UGANDA
UKRAINE
UNITED ARAB EMIRATES
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UNITED REPUBLIC OF TANZANIA
UNITED STATES OF AMERICA
URUGUAY
UZBEKISTAN
VANUATU
VENEZUELA, BOLIVARIAN REPUBLIC OF
VIET NAM
YEMEN
ZAMBIA
ZIMBABWE

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are located in Vienna.

* The name 'Türkiye' replaces the former name 'Turkey' as of 26 May 2022.

The Agency

173
Member States

2 568
professional and general service staff

€384.33 million
total Regular Budget for 2021*

extrabudgetary expenditures in 2021
€84 million

2 liaison offices
New York
Geneva

2 safeguards regional offices
Tokyo · Toronto

146
countries and territories receiving support through the Agency's technical cooperation programme

including 34 least developed countries

15
international laboratories
Vienna · Seibersdorf · Monaco

11

multilateral conventions
nuclear safety · nuclear security · nuclear liability

* At the United Nations average rate of exchange of US $0.843 to €1.00. The total Regular Budget was €392.85 million at the US $1.00 to €1.00 rate.

at a Glance 2021

973

active technical cooperation projects

133

active coordinated research projects to develop new technology

186

States with safeguards agreements in force of which

138 **States had additional protocols in force**

56

active

IAEA Collaborating Centres

designated Member State institutions supporting Agency activities

visitors a month to **iaea.org**

English version

1 000 000

up **25%** since 2020

other languages

210 000

up **61%** since 2020

over

1 million

materials available in the IAEA library

151

IAEA publications issued in 2021

As of 31 December 2021

The Board of Governors

The Board of Governors oversees the ongoing operations of the Agency. It comprises 35 Member States and generally meets five times a year, or more frequently if required for specific situations.

In the area of nuclear technologies, in the course of 2021 the Board considered the *Nuclear Technology Review 2021*.

In the area of safety and security, the Board discussed the *Nuclear Safety Review 2021* and the *Nuclear Security Report 2021*.

As regards verification, the Board considered the *Safeguards Implementation Report for 2020*. It approved two additional protocols. The Board considered the Director General's reports on verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015). The Board kept under its consideration the issues of the implementation of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) Safeguards Agreement in the Syrian Arab Republic and the application of safeguards in the Democratic People's Republic of Korea. The Board also considered the issue of the NPT Safeguards Agreement with the Islamic Republic of Iran.

The Board discussed the *Technical Cooperation Report for 2020* and approved the Agency's technical cooperation programme for 2022–2023.

The Board considered reports on the Agency and the COVID-19 pandemic and on Agency emergency assistance to Member States.

The Board approved the recommendations contained in the *Proposal to the Board of Governors by the Co-Chairs of the Working Group on the Regular Budget and the Technical Cooperation Fund Targets for 2022–2023*.

Composition of the Board of Governors (2021–2022)

Chair:

HE Mr. SHIN Chae-hyun
Governor from the Republic of Korea

Vice-Chairs

HE Mr. Miguel Camilo RUÍZ BLANCO
Governor from Colombia

HE Ms. Dominika Anna KROIS
Governor from Poland

Argentina
Australia
Austria
Brazil
Burundi
Canada
China
Colombia
Czech Republic
Egypt
Finland
France
Germany
Guatemala
India
Ireland
Japan
Korea, Republic of
Libya
Malaysia
Mexico
New Zealand
Pakistan
Peru
Poland
Russian Federation
Senegal
Slovenia
South Africa
Spain
Switzerland
United Arab Emirates
United Kingdom of Great Britain and Northern Ireland
United States of America
Viet Nam

The General Conference

The General Conference comprises all Member States of the Agency and meets once a year in regular session.

The Conference — upon the recommendation of the Board of Governors — approved the Federation of Saint Christopher (Saint Kitts) and Nevis for membership of the Agency. At the end of 2021, the Agency's membership was 173.

The Conference adopted resolutions on the Agency's financial statements for 2020 and budget for 2022; on the Agency and the COVID-19 pandemic; on nuclear and radiation safety; on nuclear security; on strengthening the Agency's technical cooperation activities; on strengthening the Agency's activities related to nuclear science, technology and applications, comprising non-power nuclear applications, nuclear power applications and nuclear knowledge management; on strengthening the effectiveness and improving the efficiency of Agency safeguards; on the implementation of the NPT Safeguards Agreement between the Agency and the Democratic People's Republic of Korea; on the application of Agency safeguards in the Middle East; and on personnel matters, comprising the staffing of the Agency's Secretariat and women in the Secretariat. The Conference also adopted decisions on the progress made towards the entry into force of the amendment to Article XIV.A of the Statute of the Agency, approved in 1999; on the report on the promotion of the efficiency and effectiveness of the Agency's decision making process; on the report on the restoration of the sovereign equality of all members of the Agency; and on the progress made towards the entry into force of the amendment to Article VI of the Statute of the Agency, approved in 1999.


IAEA

Notes

- The *Annual Report for 2021* aims to summarize only the significant activities of the Agency during the year in question. The main part of the report, starting on page 41, generally follows the programme structure as given in *The Agency's Programme and Budget 2020–2021* (GC(63)/2). The objectives included in the main part of the report are taken from that document and are to be interpreted consistently with the Agency's Statute and decisions of the Policy-Making Organs.
- The introductory chapter, 'Overview', seeks to provide a thematic analysis of the Agency's activities within the context of notable developments during the year. More detailed information can be found in the latest editions of the Agency's *Nuclear Safety Review*, *Nuclear Security Report*, *Nuclear Technology Review*, *Technical Cooperation Report* and the *Safeguards Statement and Background to the Safeguards Statement*.
- Additional information covering various aspects of the Agency's programme is available, in electronic form only, on *iaea.org*, along with the *Annual Report*.
- The designations employed and the presentation of material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.
- The mention of names of specific companies or products (whether or not indicated as registered) does not imply any intention to infringe proprietary rights, nor should it be construed as an endorsement or recommendation on the part of the Agency.
- The term 'non-nuclear-weapon State' is used as in the Final Document of the 1968 Conference of Non-Nuclear-Weapon States (United Nations document A/7277) and in the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). The term 'nuclear-weapon State' is as used in the NPT.
- All the views expressed by Member States are reflected in full in the summary records of the June Board of Governors meetings. On 6 June 2022, the Board of Governors approved the *Annual Report for 2021* for transmission to the General Conference.

Abbreviations

AI	artificial intelligence
AFRA	African Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology
ALPS	Advanced Liquid Processing System
AP	additional protocol
ARASIA	Co-operative Agreement for Arab States in Asia for Research, Development and Training related to Nuclear Science and Technology
ARCAL	Regional Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean
ARTEMIS	Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation
CGULS	Coordination Group for Uranium Legacy Sites
CLP4NET	Cyber Learning Platform for Network Education and Training
COMPASS	IAEA Comprehensive Capacity-Building Initiative for SSACs and SRAs
CPF	Country Programme Framework
CPPNM	Convention on the Physical Protection of Nuclear Material
CRP	coordinated research project
CSA	comprehensive safeguards agreement
EPR	emergency preparedness and response
FAO	Food and Agriculture Organization of the United Nations
FRAMES	Framework for Modelling Electricity Systems
GNIP	Global Network of Isotopes in Precipitation
HLW	high level waste
IACRS	Inter-Agency Committee on Radiation Safety
IARC	International Agency for Research on Cancer
ICARO	International Conference on Advances in Radiation Oncology
ICTP	Abdus Salam International Centre for Theoretical Physics
INIR	Integrated Nuclear Infrastructure Review
INIS	International Nuclear Information System
INLEX	International Expert Group on Nuclear Liability
INMA	International Nuclear Management Academy
INPRO	International Project on Innovative Nuclear Reactors and Fuel Cycles
IPPAS	International Physical Protection Advisory Service
IRRS	Integrated Regulatory Review Service
JCPOA	Joint Comprehensive Plan of Action
KMAV	Knowledge Management Assist Visit
MSSP	Member State Support Programme
NCCP	national cancer control plan

NEM School	Nuclear Energy Management School
NKM School	Nuclear Knowledge Management School
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
NUTEC Plastics	Nuclear Technology for Controlling Plastic Pollution
OSART	Operational Safety Review Team
PACT	Programme of Action for Cancer Therapy
PPAR	Project Progress Assessment Report
RCA	Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology
ReNuAL/ReNuAL2	Renovation of the Nuclear Applications Laboratories
RSTS Laboratory	Radiation Safety Technical Services Laboratory
RT–PCR	reverse transcription–polymerase chain reaction
SALTO	Safety Aspects of Long Term Operation
SDG	Sustainable Development Goal
SIT	sterile insect technique
SLA	State-level safeguards approach
SMR	small modular reactor
SQP	small quantities protocol
SRA	State or regional authority responsible for safeguards implementation
SSAC	State system of accounting for and control of nuclear material
TR4	tropical race 4
VETLAB Network	Veterinary Diagnostic Laboratory Network
WHO	World Health Organization
ZODIAC	Zoonotic Disease Integrated Action

Overview

This chapter provides an overview of some of the programmatic activities that focused, in a balanced manner, on developing and transferring nuclear technologies for peaceful applications, enhancing nuclear safety and security, and strengthening nuclear verification and non-proliferation efforts worldwide.

For two years running, the COVID-19 pandemic continued to have a significant impact on all aspects of life around the globe. The Agency demonstrated resilience to ensure that it can continue to implement its legal obligations under relevant safeguards agreements and carry out its activities 'without stopping for a single minute.' The experience gained through the lockdowns and the novel ways of working to deliver on its mandate have helped the Agency strengthen its response to Member States' needs and programme delivery during these challenging times.

NUCLEAR TECHNOLOGY

Nuclear Power, Fuel Cycle and Nuclear Technology

Status and trends

At the end of 2021, the world's total nuclear power capacity was 389.5 gigawatts (electrical) (GW(e)), generated by 437 operational nuclear power reactors in 32 countries. During the year, over 5.2 GW(e) of new capacity was connected to the grid, from 4 pressurized water reactors and 1 pressurized heavy water reactor and 1 high-temperature reactor. During 2021, 8.7 GW(e) of capacity was retired, with the permanent shutdown of ten nuclear power reactors. Supplying 2653.1 terawatt-hours of greenhouse gas emission-free electricity, nuclear power accounted for about 10% of total global electricity generation and more than a quarter of the world's low carbon electricity production. At the end of the year, 58.1 GW(e) of capacity was under construction, comprising 56 reactors, including 10 reactors (8.8 GW(e)) where construction started in 2021.

In 2021, the Agency revised up its high case projection of the potential growth of nuclear power capacity for the first time since the Fukushima Daiichi accident in 2011. It showed a more than doubling of the currently installed capacity (394.5 GW(e)) to 792 GW(e), corresponding a 12.3%. share of global electricity production compared with the current 10%. The low case estimate saw global nuclear power capacity essentially unchanged at 394 GW(e), with nuclear power's share of global electricity generation falling to 6.3%.

International conferences

At the 28th IAEA Fusion Energy Conference (FEC 2020), key physics and technology issues around the use of nuclear fusion as a future source of energy were discussed. The Conference, attended virtually by over 4000 participants from 119 Member States, also saw the release of the upgraded IAEA Fusion Device Information System, which includes general and technical information on 134 public or private fusion devices with experimental and demonstration designs, currently in operation, under construction or being planned.

The Agency's International Conference on Radioactive Waste Management: Solutions for a Sustainable Future brought together some 900 participants from 92 Member States. At the conference, it was confirmed that existing solutions can be implemented for all types of radioactive waste, and it was recommended that early planning can improve efficiency and contribute to the sustainability of nuclear power and nuclear applications.

Energy assessment services

The Agency continued to assist Member States in energy planning to address sustainable development and climate change mitigation. It hosted 26 training events for specialists in Africa, Asia, Europe, and Latin America and the Caribbean on evaluating their energy needs including by using the Agency's energy assessment tools.

To improve understanding of the contribution of different energy sources to decarbonization in complex electricity systems, the Agency developed the Framework for the Modelling of Energy Systems (FRAMES), an integrated power system modelling tool that quantifies the value that nuclear brings to low carbon systems. FRAMES evaluates impacts on emissions, generation mix and cost of electricity. It also helps identify optimal grid integration of advanced technologies such as small modular reactors as well as non-electric applications of nuclear energy.

The Agency at the 2021 United Nations Climate Change Conference

Led by Director General Grossi, the Agency's high-profile presence at the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26) helped ensure that, for the first time, nuclear power gained a prominent place at the world's main forum on climate change and the transition to clean and reliable energy.

The Agency contributed to the COP26 debate through its unique science and evidence based approach, showing how nuclear technology is vital in both fighting the climate crisis and addressing its consequences.

In cooperation with countries and other international partners, the Agency participated in some 20 COP26 events. As the host country, the United Kingdom, along with France, the Russian Federation and the United States of America, fostered discussions on the importance of nuclear power in decarbonizing the energy system, including through joint events with the Agency. On climate change adaptation, the Agency organized and supported events on climate-smart agriculture, water resources management and ocean sciences.

Ahead of COP26, the Agency released two publications: Nuclear Energy for a Net Zero World, which highlighted the key contributions that nuclear energy makes to decarbonizing the energy system, and Nuclear Science and Technology for Climate Adaptation and Resilience, which showed how nuclear applications support sustainable land and water management, climate-smart agriculture, and the analysis and monitoring of emissions and changes in the environment.

In March 2021, the Agency launched a digital public information campaign on nuclear for climate change, to help build momentum. It had reached 9.8 million people across all platforms by the end of COP26.

At COP26 in Glasgow, Scotland, Director General Grossi discusses how the world can manage to overcome the climate crisis.

Support to operating nuclear power plants

The Agency's on-line Training Course on Nuclear Supply Chain Management and Procurement enabled Member States to learn about good practices for managing procurement and supply chain activities related to the construction, operation and maintenance of nuclear power plants (NPPs). The course was implemented utilizing the Agency's relevant virtual toolkits.

Launching nuclear power programmes

The Agency continued its assistance to newcomer countries despite the challenges caused by the COVID-19 pandemic. It conducted an Integrated Nuclear Infrastructure Review (INIR) Phase 1 mission to Uganda, an INIR Phase 2 mission to Uzbekistan and an INIR Phase 1 follow-up mission to Kenya (Fig. 1). The Agency also delivered the final INIR report to Uzbekistan during the 65th regular session of the General Conference.

FIG. 1. Completion of INIR Phase 1 follow-up mission to Kenya.

Capacity building, knowledge management and nuclear information

The Agency conducted nine Nuclear Energy Management (NEM) and Knowledge Management (NKM) Schools. That included two annual joint NEM–NKM Schools, with the Abdus Salam International Centre for Theoretical Physics; and seven NEM and NKM Schools, in Belgium with the European Nuclear Education Network, in China, in Japan, at the European Nuclear Young Generation Forum (ENYGF) in Spain, two in the Russian Federation and one in Uzbekistan (Fig. 2).

The Agency conducted nine Knowledge Management Assist Visit (KMAV) virtual missions, to Brazil, Hungary, Jordan, Mexico, Sudan and Uzbekistan, as well as three to Indonesia, reviewing their knowledge management programmes and providing recommendations for enhancement.

FIG. 2. Participants in the ENYGF NEM School in Spain.

Over the year, 124 371 new records were added to the International Nuclear Information System (INIS). This includes 16 251 full text documents. The INIS repository was accessed by over 2.4 million users, who viewed 5.6 million pages and performed 3.6 million unique searches. This was the largest number of annual users in the 50-year history of INIS and represented a 52% increase compared with the previous year.

Stakeholder involvement

The Agency supported Member States in their stakeholder engagement efforts by conducting customized interregional workshops and topical webinars, as well as various training courses, schools and peer reviews. It also released Stakeholder Engagement in Nuclear Programmes (IAEA Nuclear Energy Series No. NG-G-5.1), the first IAEA Nuclear Energy Series Guide-level publication to support national efforts to engage with stakeholders throughout the life cycle of nuclear facilities.

Assurance of supply

The IAEA Low Enriched Uranium Bank in Kazakhstan, which became operational in 2019, continued safe operations at the Ulba Metallurgical Plant.

A low enriched uranium reserve in Angarsk, established following the agreement of February 2011 between the Government of the Russian Federation and the Agency, remained operational.

Fuel cycle

The publication Spent Fuel Performance Assessment and Research: Final Report of a Coordinated Research Project (SPAR-IV) (IAEA-TECDOC-1975) provides an overview of the technical issues related to wet and dry storage of spent fuel and presents the main results and findings from a related coordinated research project (CRP).

Reactor technology development and innovation

To support research and development on integrated, sustainable energy system designs and modelling focused on small modular reactors and microreactors as well as renewable

energy technologies for multipurpose applications, the Agency designated Ontario Tech University in Canada as a Collaborating Centre for integrated energy systems with advanced nuclear power reactors.

To support the development of common industrial approaches by technology holders and users' requirements and criteria by operators, the Agency started two parallel projects 'Generic User Requirements and Criteria (GURC) of Small Modular Reactor Technologies for Near Term Deployment' and 'Codes and Standards, Design Engineering and Manufacturing of Components of Small Modular Reactors'. In 2021, the related activities were integrated within new Agency-wide initiatives on harmonization and standardization for advanced reactors and the Platform on Small Modular Reactors and their Applications (see related box).

The Agency held webinars highlighting the role of international collaboration in developing and deploying new nuclear power technologies focusing on topics such as enhancing the technological competitiveness of SMRs for near term deployment and the potential role of microreactors.

Research reactors

The Agency upgraded its Research Reactor Database to offer enhanced functionality for users.

The Agency resumed Integrated Nuclear Infrastructure Review for Research Reactors missions with in-person participation of many stakeholders. The first such mission since the beginning of the COVID-19 pandemic assisted Thailand.

Launch of the Agency-wide Platform on Small Modular Reactors and Their Applications

As elaborated in *Technology Roadmap for Small Modular Reactor Deployment* (IAEA Nuclear Energy Series No. NR-T-1.18), published in 2021, global interest in small modular reactors (SMRs) has been increasing due to their potential for flexible power generation for a wider range of users and applications, and as a replacement for ageing fossil fuel-fired power plants. They are also expected to offer enhanced safety features, lower upfront costs and suitability for cogeneration and non-electric applications. In addition, SMRs may offer options for remote regions and for nuclear–renewable hybrid energy systems.

To respond to the growing interest, the Agency-wide Platform on SMRs and their Applications was established to coordinate the Agency's activities on SMRs and provide 'one-stop shop' support for Member States and stakeholders. The Platform brings together all Agency expertise on the development, early deployment and oversight of SMRs and their applications in an effective and efficient manner, providing comprehensive managerial and technical support.

In its first year, the Platform was tasked with developing a medium term strategy (2022–2027) for support for Member States, and an SMR Coordination and Resource Portal for Information Exchange, Outreach and Networking. It also prepared a broad proposal for an interregional project under the technical cooperation programme entitled 'Supporting Member States' Capacity Building on Small Modular Reactors and Microreactors and their Technology and Applications — A Contribution of Nuclear Power to the Mitigation of Climate Change'. The Platform is now developing a high-level publication provisionally entitled *Small Modular Reactors: A New Nuclear Energy Paradigm*, which will summarize the enabling factors to be considered by policymakers in the decision and deployment phases for SMRs. It has also begun addressing the first requests for support received from Member States.

The Agency and the Reactor Institute Delft in the Netherlands expanded cooperation in neutron activation analysis (NAA) to neutron-beam based methodologies, a key technique in materials research, biology and medicine. To this end, the Agency re-designated the institute as a Collaborating Centre for NAA and neutron-beam based methodologies.

The Agency continued to expand its suite of remote tools for capacity building using research reactors and for sustainable operation and effective utilization of research reactors. Two Internet Reactor Laboratories, hosted in the Czech Republic and the Republic of Korea, started transmission of experiments to students (Fig. 3). Two e-learning courses were expanded, and a new course was launched.

Radioactive waste management

The Agency designated the Beijing Research Institute of Uranium Geology in Beishan, China as a Collaborating Centre, the first such Centre in the field of geological disposal of high level waste (HLW). Given the ongoing development of underground research laboratories (URLs) worldwide, the Collaborating Centre will contribute to international research on safe disposal of HLW (see related case study).

The Agency's Spent Fuel and Radioactive Waste Information System (SRIS) aims to facilitate information sharing and simplify national reporting in a single, easy-to-use platform. During 2021, Member States shared data on spent fuel and radioactive waste management through SRIS, which is hosted on the Agency's public web site. Development of the SRIS was achieved in close cooperation with the European Commission and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development.

Decommissioning and environmental remediation

The Agency established a Technical Working Group on Decommissioning and Environmental Remediation, whose first meeting focused on the interface between the regulator and the operator, use of new and advanced technologies for decommissioning and environmental remediation, global status and trends in decommissioning, and sharing of information on successful remediation projects.

Nuclear fusion

The Agency launched a new project entitled 'Synergies in Technology Development between Nuclear Fission and Fusion for Energy Production' identifying areas where fission technology can benefit fusion technology development and advising on how this knowledge can be transferred and shared.

FIG. 3. Transmission of a research reactor experiment by the Internet Reactor Laboratory.

The seventh Demonstration Fusion Power Plant (DEMO) Programme Workshop, a platform to facilitate international collaboration on defining and coordinating DEMO programme activities, held virtually, identified good practices on regulation of future nuclear fusion power plants, including aspects of safety and security, radioactive waste management and considerations for safeguards.

Nuclear data

The Agency improved its nuclear data libraries used for verification purposes by updating the IAEA Handbook of Nuclear Data for Safeguards with fission yield information and improved (alpha.n) nuclear reaction data for criticality issues in both nuclear power and safeguards applications.

Accelerator technology and its applications

The Agency and the University of Paris-Saclay in France established a strategic partnership to enhance the use of nuclear technology in the field of characterization and preservation of cultural and natural heritage. The university has become the first Atoms for Heritage Collaborating Centre.

The Agency and South Africa's iThemba Laboratory for Accelerator-Based Sciences (iThemba LABS), agreed to jointly promote and strengthen the use of accelerator-based science, technology and applications. As a result, iThemba LABS was designated as a Collaborating Centre in the area of accelerator-based scientific research and applications.

Nuclear instrumentation

The Agency designed, constructed and commissioned its deuterium–deuterium based neutron generator as part of the Neutron Science Facility in Seibersdorf, Austria (Fig. 4). This new state of the art infrastructure will offer training and practical applications with neutrons. These include demonstration experiments, such as neutron activation analysis, neutron radiography/tomography, delayed neutron counting, neutron detection experiments as well as radiation protection practices.

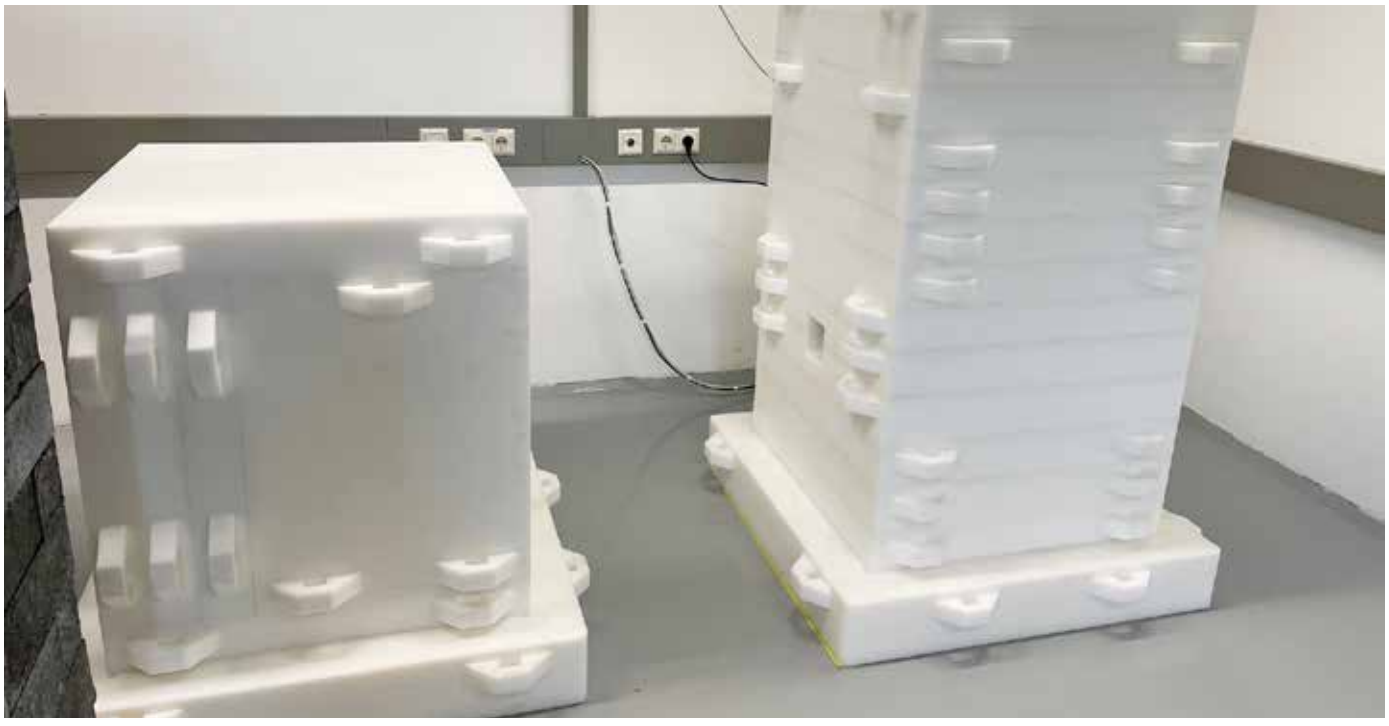

FIG. 4. The shielding assembly housing the deuterium–deuterium neutron generator during its commissioning phase.

NUCLEAR SCIENCES AND APPLICATIONS

Third International Conference on Advances in Radiation Oncology

The third International Conference on Advances in Radiation Oncology (ICARO-3) was held in February 2021, providing a platform for health care professionals to review the current developments in clinical applications in the fields of radiation oncology, radiation biology and medical physics, with a view to addressing the challenges of appropriate cancer management in Member States. The conference also examined the pivotal role of emerging radiotherapy techniques in tackling the health challenges common to many Member States. ICARO-3 was conducted as a fully virtual event and featured over 2500 minutes of live and recorded content in 30 broadcast and 10 on-demand sessions. More than 300 participants and over 3000 observers from 142 Member States and 3 non-Member States participated in ICARO-3.

Second International Joint Symposium on Remediation of Radioactive Contamination in Agriculture: Next Steps and Way Forward

The Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture works closely with a wide range of organizations and universities worldwide to enhance readiness and capabilities of societies to optimize remediation of agricultural areas affected by large scale nuclear accidents. In October 2021, the Joint FAO/IAEA Centre held — in collaboration with the National Agriculture and Food Research Organization of Japan — the second International Joint Symposium on Remediation of Radioactive Contamination in Agriculture: Next Steps and Way Forward. Based on research carried out in Japan and through an international research network, coordinated by the Joint FAO/IAEA Centre, the symposium showed how remediation can be further optimized through new experimental methods, modelling techniques and decision-support systems.

Artificial intelligence for nuclear technology and applications

Artificial intelligence (AI) is becoming an increasingly valuable tool for the processing of large amounts of data and the development of predictive models. The Agency organized the Technical Meeting on Artificial Intelligence for Nuclear Technology and Applications, which covered related programmatic activities in nuclear energy, nuclear sciences and applications, nuclear safety and security, and nuclear safeguards. The meeting identified potential areas for new activities on AI for nuclear applications aimed at, among others, developing predictive models to assess the impacts of climate change, supporting diagnosis and treatment of cancer, enabling early-stage detection and impact assessment of zoonotic diseases as part of the Agency's ZODIAC initiative, optimizing smart agricultural practices, and other applications that require the processing of large amounts of data. The Agency joined the United Nations International Telecommunication Union (ITU) in 2021 in organizing the AI for Good Global Summit alongside 37 other United Nations system organizations and contributed to the report on *United Nations Activities on Artificial Intelligence (AI)* 2021 published by ITU, with the findings from the Agency's Technical Meeting.

ReNuAL2 progresses towards construction launch

The final phase of the Renovation of the Nuclear Applications Laboratories (ReNuAL) initiative in Seibersdorf, launched as 'ReNuAL2' by the Director General in September 2020, made strides with the completion of detailed architectural designs for the required new facilities, issuance of a construction contract for bids, and continued strong resource

Unveiling of a new ReNuAL2 donor recognition display during a General Conference side event in September 2021.

mobilization momentum. ReNuAL2 includes three main elements: construction of a new building for three laboratories (the Nuclear Science and Instrumentation Laboratory, the Terrestrial Environmental Radiochemistry Laboratory and the Plant Breeding and Genetics Laboratory), refurbishment of the Dosimetry Laboratory and the replacement of greenhouses. These modern facilities will strengthen the laboratories' support for Member States in the areas of climate-smart agriculture, environmental resource management and food security.

ZODIAC: Zoonotic Disease Integrated Action
IAEA Scientific Forum— Preparing for Zoonotic Outbreaks: The Role of Nuclear Science

The 2021 IAEA Scientific Forum, held on the margins of the 65th regular session of the General Conference, focused on the role of nuclear science in detecting zoonotic diseases, and on the Agency's support to its Member States in strengthening their preparedness and ability to respond in a timely way to zoonotic outbreaks. The Forum was attended by the Heads of the Food and Agriculture Organization of the United Nations, the World Organisation for Animal Health and the World Health Organization, as well as representatives from international initiatives such as the One Health High-Level Expert Panel, Preventing Zoonotic Disease Emergence (PREZODE) and Eklipse.

The Forum, which attracted over 3000 on-line viewers, featured the Agency's Zoonotic Disease Integrated Action (ZODIAC) initiative. It presented how ZODIAC aims to build the capacities of designated national laboratories around the world to use nuclear and related techniques safely for the early, rapid and accurate detection of transboundary animal and zoonotic diseases, and to carry out targeted research. ZODIAC currently comprises some 150 Member States who have designated ZODIAC National Coordinators and more than 120 ZODIAC National Laboratories in Africa, Asia and the Pacific, Latin America and the Caribbean, and Europe.

The Forum concluded that closer coordination, collaboration and communication on the research, early detection and monitoring of zoonotic diseases will benefit scientific advancement and are key to preventing or containing the next epidemic or pandemic. A Letter of Intent was signed between the Agency and PREZODE on the sidelines of the Forum — a concrete expression of this collaborative drive.

Director General Grossi and representatives of Belgium, France, Japan and the United States of America, as well as representatives of the African Centre of Excellence for Genomics of Infectious Diseases, Eklipse, the One Health High-Level Expert Panel and PREZODE, at the closing session of the 2021 IAEA Scientific Forum.

NUTEC: Nuclear Technology for Controlling Plastic Pollution

The Agency has set up the Nuclear Technology for Controlling Plastic Pollution (NUTEC Plastics) initiative to assist Member States in integrating nuclear techniques as part of their efforts to address the challenges of plastic pollution. NUTEC Plastics consolidates and builds on the Agency portfolio in the areas of plastic recycling using radiation technology and marine monitoring of microplastics using isotopic tracing techniques. The goal is to support a better understanding of the volume and impact of marine plastic pollution, and to reduce the amount of plastic waste.

In 2021, Director General Grossi chaired four regional roundtable discussions with ministers, high level officials and experts from industry and academia from Asia and the Pacific, North, Central and South America and the Caribbean, Africa, and Europe and Central Asia, as well as from international organizations including the United Nations Secretary-General's Special Envoy for the Ocean, to discuss ongoing efforts, innovative solutions and partnerships to tackle plastic pollution. The roundtables highlighted the unique contributions that nuclear technologies can make in the fight against plastic pollution both globally and regionally.

Follow-up activities to the four roundtables have already begun. In the Asia and the Pacific region, over ten countries are actively conducting research and development (R&D) in radiation technology for plastic recycling. Several countries have reached an advanced stage in their R&D and have the potential to pursue pilot-scale recycling. In Europe, 18 countries are working together to enhance the coastal management of plastic pollution in the Aral Sea, the Black Sea, the Caspian Sea and the Mediterranean Sea. Following the roundtable for the Americas and the Caribbean, plans are under way to strengthen regional capacity in microplastic monitoring and analysis. In the Africa region, an action plan has been prepared to coordinate activities in this area, and consultations with Member States on feasibility studies for plastic waste monitoring are ongoing.

The NUTEC Plastics roundtable for Europe and Central Asia, held virtually in October 2021.

Food and Agriculture

Mutation breeding for disease control in tropical plants

Two important diseases threatening tropical crops are tropical race 4 (TR4), which causes Fusarium wilt in banana crops, and coffee leaf rust, which both affect smallholder farmers and large scale exporters. The Joint FAO/IAEA Centre has targeted these two diseases over recent years using mutation breeding and associated biotechnologies. In 2021, a laboratory-based screening method for detecting resistance to TR4 in banana plantlets was established, involving inoculation of plants raised from tissue culture and monitoring under controlled conditions. Within the context of a CRP, a TR4-resistant mutant variety of banana, and several putative TR4-resistant mutant lines were identified. A large scale mutagenesis experiment in banana plants is in progress combining genomics analysis to identify DNA variants that are contributory to resistance. To combat coffee leaf rust, and to enable crop improvement in coffee in general, a single-cell mutagenesis and regeneration system was established at the Plant Breeding and Genetics Laboratory during the year.

Isotopic tracing to identify sources of greenhouse gases from agriculture

In 2021, the Joint FAO/IAEA Centre developed and validated new methods for the precise measurement of greenhouse gas (GHG) emissions to quantify and identify their production process in agriculture. Comprehensive guidelines were published detailing practical methods for applying nitrogen-15 tracing techniques to accurately measure emissions of nitrous oxide (N_2O), a GHG that is 300 times more potent than carbon dioxide, and to identify the precise sources of N_2O for its effective mitigation. The nitrogen-15 tracing techniques have been used successfully by researchers in Bangladesh, Brazil, China, Costa Rica and Pakistan.

Improvement of the sterile insect technique package for human disease vectors, particularly Aedes mosquitoes

Ionizing radiation to sterilize male insects is a major component of the sterile insect technique (SIT) for managing mosquito disease vectors to reduce the associated disease burden. Collection of entomological baseline data in the target area, mass-production of insects and their quality evaluation, irradiation, handling, transporting and release procedures of sterile males are required to apply SIT in an area-wide integrated pest management approach for managing mosquito vector populations. A significant cost reduction of the mass rearing process was achieved in 2021, and procedures for the irradiation of adult mosquitoes developed. The SIT field trials are currently implemented in several Member States, with successful suppression of adult mosquito populations being recorded on a small scale in eight countries. In addition, the collaboration between the Joint FAO/IAEA Centre and the World Health Organization (WHO) has been strengthened.

Human Health

Development of the first international body composition reference charts for infants based on stable isotopes

The stable isotope technique of deuterium dilution is utilized to assess body composition. The interpretation of body composition data requires reference charts. However, there had previously not been any international references for body composition in children aged 0–2 years. In 2021, the Agency created international body composition reference charts for

children 0–2 years based on the deuterium dilution technique. These charts will support accurate monitoring and evaluation of body composition in infants for public health guidance, as well as clinical evaluation.

The Lancet Oncology Commission on Medical Imaging and Nuclear Medicine

The diagnosis and treatment of patients with cancer requires access to imaging to ensure accurate management decisions and optimal outcomes. A global assessment of imaging and nuclear medicine resources conducted through the Lancet Oncology Commission on Medical Imaging and Nuclear Medicine identified substantial shortages in equipment and workforce, particularly in low and middle income countries. The drafting and the coordination of the report, which were led by the Agency and published in March 2021, highlights inequalities in access to imaging resources and proposes actions to produce extensive health and economic benefits and reduce the burden of cancer globally. The Lancet Commission comprises leading nuclear medicine and diagnostic imaging societies and organizations and is the first ever comprehensive effort to assess the needs for imaging and nuclear medicine resources worldwide.

Promoting quality assurance in medical physics through guidance and dosimetry services

Technologies in radiation medicine evolve continuously. Quality assurance programmes ensure appropriate, safe and effective use of the complex equipment that is used for the diagnosis and treatment of patients. To support these efforts in 2021, the Agency produced technical guidance on the safe delivery of radiation treatment and on the certification of medical physicists. Medical physicists are responsible for the technical aspects of quality control; this not only includes the correct functioning of the equipment, but also the optimization of the radiation dose delivered to each patient. In addition, the Agency expanded its radiotherapy dosimetry audit services to include newly commissioned electron beams used for the treatment of skin and other superficial cancers.

Environment

Beginning the process for accreditation of the IAEA Environment Laboratories as a producer of environmental reference materials characterized for gamma emitting radionuclides

The Agency pursued accreditation of the IAEA Environment Laboratories for reference material production in a multi-year effort to further improve the Agency's services to Member State laboratories. A comprehensive quality management system was established, supporting the production of reference materials in the IAEA Environment Laboratories in Seibersdorf and Monaco. This quality management system was finalized in 2021 after being audited by an external accreditation body to support the accreditation of the IAEA Environment Laboratories for the production of environmental reference materials characterized for gamma emitting radionuclides.

Support to Sri Lanka to develop and implement a comprehensive, long term programme for identifying and monitoring post-spill marine pollution in coastal environments

Following the accident of the container ship X-Press Pearl off the coast of Colombo, Sri Lanka, the Agency supported the country's emergency response for mitigating the worst ever marine ecological disaster in the area. On the request of the local Government, endorsed by the Sri Lanka Atomic Energy Board, an Agency virtual expert mission helped

local authorities outline Sri Lanka's top priority needs. The Agency is now providing targeted nuclear-related technology to assess and monitor marine pollution in the wake of the disaster.

Water Resources

Renewing the Global Network of Isotopes in Precipitation

Scientific advances in data evaluation and processing have resulted in the opportunity to further build and expand on the Global Network of Isotopes in Precipitation (GNIP). In this light, the Agency and the World Meteorological Organization have signed a revised Memorandum of Understanding on GNIP to make it fit for purpose in evaluating the impact of climate change on global water resources. Using GNIP, the Agency's established Regionalized Cluster-based Water Isotope Prediction framework was expanded to globally map naturally occurring tritium in precipitation.

The Fukushima Prefecture Initiative Project for improvements in tritium analysis

The Fukushima Prefecture Initiative Project for improvements in tritium analysis was completed in 2021. This project enhanced the capacity of the Fukushima Prefecture to perform tritium analyses on various types of environmental samples (water, soil, plants and animal tissue). As part of this project, a tritium enrichment system, designed by the Agency's Isotope Hydrology Laboratory, was installed in Fukushima Prefecture. Technical staff in Fukushima Prefecture were trained in the use of the equipment and quality assurance/quality control procedures for processing the tritium data. These activities are essential for the Prefecture to be able to promptly provide independent analytical results to its residents.

Source tracking of water pollution with nitrate isotopes

Nitrate contamination affects access to clean drinking water. At the Isotope Hydrology Laboratory, improved analysis of stable isotopes in nitrate (δ15N and δ18O) provided a better understanding of the sources and processes involved in atmospheric and water pollution. This was tested through detailed analysis of daily precipitation in Vienna. To further this work, a new CRP was initiated in 2021 that will look at better differentiation of nitrate pollution sources by combining nitrate isotopes with contaminants of emerging concern in surface and groundwater samples.

Radioisotope Production and Radiation Technology

New coordinated research project on production and quality control of actinium-225 radiopharmaceuticals to support local production in Member States

In cancer treatment, targeted alpha therapy (TAT) has recently demonstrated encouraging clinical results that are drawing significant attention from the research community, clinicians and professional societies. The main limitation for the broad application of TAT is the availability of suitable radionuclides, as well as approved guidelines and protocols for the production and quality control of these radiopharmaceuticals. Therefore, a new Agency CRP was initiated, aimed at the development, production and quality control of a new generation of TAT radiopharmaceuticals, with focus on actinium-225 radiopharmaceuticals.

Training and capacity building for Member States in applications of radiation technologies

The Agency delivered training events on applications of radiation technologies to more than 500 participants from almost 100 Member States. These events, conducted jointly with leading institutions in the fields of radioisotope production, radiopharmaceuticals and radiation technology, provided advanced technical knowledge and networking opportunities for the participants, with an emphasis on how to engage end users of the technology.

NUCLEAR SAFETY AND SECURITY

Nuclear Safety

Safety standards and their application

The Agency issued seven Specific Safety Guides after endorsement by the Commission on Safety Standards (CSS). It conducted 31 safety related peer review and advisory service missions to support 23 Member States in their application of Agency safety standards.

The Agency performed a gap analysis to consider whether the safety standards required revision or strengthening following experience related to the COVID-19 pandemic. After a review of the analysis by the Safety Standards Committees, the CSS concluded that revising the safety standards in light of the COVID-19 pandemic was not a priority at this time and that the Agency should continue collecting and assessing experience in Member States for future consideration.

International conferences

The Agency organized the International Conference on the Development of Preparedness for National and International Emergency Response (EPR2021) in October 2021, where

International Conference on the Development of Preparedness for National and International Emergency Response (EPR2021).

participants exchanged experiences on the progress made and the challenges encountered at both national and international levels in emergency preparedness and response (EPR), and identified key priorities in further improving readiness for nuclear and radiological incidents and emergencies.

The Agency organized the International Conference on the Safe and Secure Transport of Nuclear and Radioactive Materials virtually in December 2021. Member States exchanged good practices on the safe and secure transport of nuclear and radioactive materials and discussed potential needs in managing the interface between transport safety and transport security.

Nuclear Safety Ten Years After the Fukushima Daiichi Accident

Following the accident at Tokyo Electric Power Company's (TEPCO's) Fukushima Daiichi NPP, lessons learned, as well as ongoing nuclear safety challenges facing the nuclear industry, were identified. These include topics such as minimizing the possibility of serious off-site radioactive releases; supporting robust preparedness arrangements; attributing health effects of ionizing radiation exposure and inferring risk; safety considerations for nuclear development; building inclusive safety leadership; the role and effectiveness of international legal instruments; and communication with the public, stakeholder engagement and trust building.

These topics were part of the technical discussions at the International Conference on a Decade of Progress After Fukushima-Daiichi: Building on the Lessons Learned to Further Strengthen Nuclear Safety, held in November 2021 in Vienna. The conference brought together around 900 participants from 68 Member States, in order to identify ways to further strengthen nuclear safety. Experts and representatives from nuclear regulators, operators, governments, technical support organizations and the industry contributed to informative technical sessions and engaging panel discussions. Additionally, the conference included a dedicated youth panel, comprised of winners from a related nuclear safety essay contest, who discussed a wide range of nuclear issues relevant to students and early career professionals.

Outcomes from the conference, including a President's Call for Action, will be important tools for the international community to further enhance nuclear safety globally.

Director General Grossi addressing the International Conference on a Decade of Progress After Fukushima-Daiichi: Building on the Lessons Learned to Further Strengthen Nuclear Safety.

Mike Weightman, Conference President, chairing the Panel Maintaining the Momentum at the conference.

An Agency team visits Fukushima Daiichi NPP as part of the Agency's ALPS treated water safety review.

Advanced Liquid Processing System treated water

The Agency conducted a series of on-site and virtual technical exchanges in preparation for the first mission of the Task Force review that will assess the Government of Japan's plan to discharge Advanced Liquid Processing System (ALPS) treated water against relevant international safety standards. These preparatory activities focused on reviewing the Government of Japan's self-assessment, and the radiological impact assessment that was published by TEPCO, the operator of the Fukushima Daiichi NPP, in November 2021. As proposed by the Director General, the Agency's work on the plan will take place before, during and after its implementation.

Safety of NPPs, research reactors and fuel cycle facilities

The Agency held a virtual Technical Meeting on the Use of Periodic Safety Reviews for Long Term Operation of Nuclear Power Plants. The Agency completed the preparation

of a new Safety Report that describes current challenges, synergies, good practices, and examples of corrective actions and safety improvements related to the application of periodic safety reviews for justifying long term operation of NPPs.

The Agency published the revised *SALTO Peer Review Guidelines* (IAEA Services Series No. 26 (Rev. 1)).

Safe and secure deployment of advanced reactors, including SMRs

The Agency organized a Technical Meeting on Next Generation Reactors and Emergency Preparedness and Response, where participants discussed, inter alia, the graded approach to EPR for next generation reactors; the status of SMR design and deployment in Member States; non-reactor technical aspects of developing off-site EPR arrangements; transportable SMRs; and the development of approaches, methodologies and criteria for determining the technical basis for an emergency planning zone for SMRs.

The Agency completed the review of the applicability of the safety standards to SMRs and non-water cooled reactors. The review confirmed the overall applicability of the Agency safety standards to these technologies, but also identified areas that require further work. The review included consideration of the life cycle of these technologies as well as the safety–security–safeguards considerations and challenges. This work was captured in a Safety Report on this topic, which will be published in 2022.

Assisting countries embarking on a new nuclear power programme

The Agency launched a project on capacity building on site safety assessment in embarking countries to enhance the capacity of regulatory bodies for reviewing safety analysis reports related to site and design aspects.

Incident and emergency preparedness and response

The Agency conducted a Level 3 Convention Exercise in October 2021, hosted by the United Arab Emirates, to test the international arrangements for response to a major nuclear emergency.

Radioactive waste management, environmental assessments and decommissioning of nuclear facilities

The Agency continued developing guidance on the conduct of Integrated Regulatory Review Service and Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation back-to-back missions.

The Agency held the virtual Annual Meeting of the Coordination Group for Uranium Legacy Sites (CGULS) to continue information exchange and coordinate future activities of Member States and international organizations participating in CGULS.

Radiation protection

The Agency held five Postgraduate Educational Courses in Radiation Protection and the Safety of Radiation Sources, in Algeria, Argentina, Belarus, Ghana and Jordan, in different languages.

In 2021, the Inter-Agency Committee on Radiation Safety (IACRS) commemorated the 30th anniversary of its creation. The IACRS is comprised of eight intergovernmental organizations, including the Agency and five non-governmental bodies that work together towards international harmonization of radiation protection and safety. During its 30 years of service, the IACRS has had many achievements, primarily playing a key role in the

development and review of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources.

Capacity building in nuclear, radiation, transport and waste safety, and in emergency preparedness and response

The Agency conducted 343 capacity building activities on nuclear, radiation, transport and waste safety, and emergency preparedness and response.

The Agency held a virtual International School on Nuclear and Radiological Leadership for Safety in June 2021 and an International School on Nuclear and Radiological Leadership for Safety in Greece in November–December 2021.

The Ibero-American Forum of Radiological and Nuclear Regulatory Agencies approved its Action Plan for 2021–2023 and a new project on security in the transport of radioactive material at its annual plenary meeting in July 2021.

The Agency published an educational handbook on safety culture in medical uses of radiation, entitled *Radiation Safety Culture Trait Talks*, which is structured around ten principles, or traits, that contribute to a strong safety culture.

Safety conventions

The Agency facilitated the Organizational Meeting for the Joint Eighth and Ninth Review Meeting of the Contracting Parties to the Convention on Nuclear Safety in October 2021, where participants, inter alia, confirmed the Officers and the composition of Country Groups for the Joint Eighth and Ninth Review Meeting.

Codes of conduct

The Agency held a virtual International Meeting on the Application of the Code of Conduct on the Safety of Research Reactors, where participants discussed and exchanged experience on the safety status of their research reactors and experience in application of the provisions of the Code.

Regarding the Code of Conduct on the Safety and Security of Radioactive Sources, the number of Member States committed to acting harmoniously with its supplementary Guidance on the Import and Export of Radioactive Sources increased to 123, and the number of Member States that have committed to implementing its other supplementary Guidance on the Management of Disused Radioactive Sources grew to 44 in 2021.

The Agency's Radiation Safety Technical Services Laboratory

The Radiation Safety Technical Services (RSTS) Laboratory has once again been re-accredited for meeting the highest levels of quality in compliance with International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) standards, through an external assessment audit. The RSTS Laboratory was first accredited according to ISO/IEC 17025 in 2006 and has consistently and satisfactorily passed all the surveillance audits, reconfirming its technical capabilities. The RSTS Laboratory operates at the Vienna International Centre and the IAEA Seibersdorf laboratories, and is responsible for providing radiation monitoring services to individuals, including Agency staff, experts, trainees and visitors, who may be exposed to radiation during Agency activities.

The Agency's Radiation Safety and Nuclear Security Regulator

The Agency's Radiation Safety and Nuclear Security Regulator authorized the operation of the new Neutron Science Facility, approved the final safety analysis report of the Yukiya Amano Laboratories, and reviewed and assessed the safety case for the new

'Flexible Modular Laboratory 2' in Seibersdorf. In addition, a procedure for clearance from regulatory control of material used in the Nuclear Material Laboratory was approved. An internal regulatory guidance document on cross-Divisional activities involving radiation exposure was formally issued.

A comprehensive self-assessment of the Agency's regulatory infrastructure was conducted following the same methodology that is recommended by the Agency for its Member States using the on-line tool Self-Assessment of Regulatory Infrastructure for Safety (eSARIS).

Civil liability for nuclear damage

At the request of the Contracting Parties to the Convention on Supplementary Compensation for Nuclear Damage (CSC), the Agency organized the Preparatory Meeting for the Second Meeting of the Contracting Parties and Signatories to the CSC in a virtual format in February.

In April, the International Expert Group on Nuclear Liability (INLEX), which provides advice to the Director General and the Director of the Office of Legal Affairs on issues relating to civil liability for nuclear damage, held its 21st regular meeting virtually. The Group discussed liability issues concerning nuclear fusion facilities, the limitations on the operator's right of recourse under the nuclear liability conventions and the exclusion of on-site property damage from the operator's liability for nuclear damage.

With the assistance of INLEX members and in cooperation with Indonesia, the Agency hosted a virtual sub-regional Workshop on Civil Liability for Nuclear Damage for ASEAN Plus Three. In the context of the Agency's legislative assistance programme, support was provided to Member States in the development of national legislation, including on legislation related to civil liability for nuclear damage to seven Member States.

Nuclear Security

The Convention on the Physical Protection of Nuclear Material and its Amendment

The Agency continued encouraging universal adherence to and effective implementation of the Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment and provided assistance, upon request, in this regard. Two more States became party to the CPPNM and two States became party to its Amendment in 2021.

The Agency intensified its efforts in 2021 to assist Parties in preparing for the Conference of the Parties to the Amendment to the Convention on the Physical Protection of Nuclear Material, planned to be held from 28 March to 1 April 2022, in line with Article 16.1 of the CPPNM as amended. The Agency held a virtual meeting of the Preparatory Committee for the Conference in February 2021, a series of virtual regional meetings through November and December 2021 and two rounds of open-ended consultations in October and December 2021.

Capacity building and outreach

During 2021, the Agency provided assistance in drafting nuclear security regulations to eight Member States. It also conducted 103 training events for more than 7900 participants from 137 States and continued to deliver its e-learning activities, with over 1500 users from 125 States completing over 2600 modules. Three e-learning modules were translated and made available in Arabic, Chinese, English, French, Russian and Spanish during the reporting period, bringing the total number of e-learning modules available in the six languages to 18.

Ground breaking ceremony for new Nuclear Security Training and Demonstration Centre (NSTDC) at Seibersdorf, July 2021.

In July, the Agency held the ground breaking ceremony to establish a Nuclear Security Training and Demonstration Centre at its Seibersdorf laboratories which will provide optimal support to States through the use of state of the art technical infrastructure and equipment. Once completed, this specialized training facility will complement and fill gaps in training capabilities that do not commonly exist among institutions in States and will further enhance Member States' capacity building, upon request, with advanced technology and expertise.

Interfaces between nuclear safety and security

The Agency continued to address the interfaces between nuclear safety and security, while recognizing their distinctions. Two publications addressing the topic were issued — *The Nuclear Safety and Nuclear Security Interface: Approaches and National Experiences* (Technical Reports Series No. 1000) and *Managing the Interface between Safety and Security for Normal Commercial Shipments of Radioactive Material* (Technical Reports Series No. 1001). The Agency continued to develop training materials and conduct training courses to support Member States in managing the interface between nuclear safety and nuclear security for nuclear installations, radioactive sources and transport.

In October 2021, the Agency organized a Technical Meeting on the Use of Safety Analysis Approaches for Nuclear Security Purposes. Participants from Member States discussed current practices, challenges and potential ways that the insights from safety analysis (both probabilistic and deterministic) could be used to support nuclear security considerations.

Nuclear Security Plan 2022–2025

The Agency published the Nuclear Security Plan 2022–2025, after extensive consultations with Member States and approval by the Board of Governors. The new Plan highlights the Agency's nuclear security activities that are planned to be undertaken using voluntary contributions to the Nuclear Security Fund. The Plan takes into account the priorities of Member States, expressed through the resolutions and decisions of the Agency's Policy-Making Organs, as well as priority setting for Nuclear Security Series publications based on recommendations of the Nuclear Security Guidance Committee.

NUCLEAR VERIFICATION[1,2]

Implementing safeguards and other verification activities in 2021 remained challenging as a result of the global COVID-19 pandemic. For example, Agency inspectors and technicians on missions spent a total of more than 2100 days in quarantine outside Austria. Nevertheless, with considerable sustained effort and continued adaptation to the circumstances, the Agency carried out over 3000 verification activities (2850 in 2020) and spent more than 14 600 days in the field conducting those activities (12 700 in 2020). This ensured that the Agency was able to draw soundly based conclusions for all States in which safeguards were implemented by the Agency for 2021.

Implementation of safeguards in 2021

At the end of every year, the Agency draws a safeguards conclusion for each State for which safeguards are applied. This conclusion is based on an evaluation of all safeguards relevant information available to the Agency in exercising its rights and fulfilling its safeguards obligations for that year.

In 2021, safeguards were applied for 185 States[3,4] safeguards agreements in force with the Agency. Of the 132 States that had both a comprehensive safeguards agreement (CSA) and an additional protocol (AP) in force, the Agency drew the broader conclusion that *all* nuclear material remained in peaceful activities for 72 States[5] (for 69 of which[6] integrated safeguards were implemented during the whole of 2021); for the remaining 60 States, as the necessary evaluation regarding the absence of undeclared nuclear material and activities for each of these States remained ongoing, the Agency concluded only that *declared* nuclear material remained in peaceful activities. For 45 States with a CSA but with no AP in force, the Agency concluded only that *declared* nuclear material remained in peaceful activities.

Safeguards were also implemented with regard to nuclear material in selected facilities in the five nuclear-weapon States party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) under their respective voluntary offer agreements. For these States, the Agency concluded that nuclear material in the selected facilities to which safeguards had been applied remained in peaceful activities or had been withdrawn from safeguards as provided for in the agreements. The Agency also implemented safeguards for three States not party to the NPT pursuant to item-specific safeguards agreements based on INFCIRC/66/Rev.2. For these States, the Agency concluded that nuclear material, facilities or other items to which safeguards had been applied remained in peaceful activities.

As of 31 December 2021, eight States Parties to the NPT had yet to bring CSAs into force pursuant to Article III of the Treaty. For these States Parties, the Agency could not draw any safeguards conclusions.

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1 The designations employed and the presentation of material in this section, including the numbers cited, do not imply the expression of any opinion whatsoever on the part of the Agency or its Member States concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

2 The referenced number of States Parties to the Treaty on the Non-Proliferation of Nuclear Weapons is based on the number of instruments of ratification, accession or succession that have been deposited.

3 These States do not include the Democratic People's Republic of Korea (DPRK), where the Agency did not implement safeguards and, therefore, could not draw any conclusion.

4 And Taiwan, China.

5 And Taiwan, China.

6 And Taiwan, China.

Conclusion of safeguards agreements and APs, and amendment and rescission of small quantities protocols

The Agency continued to facilitate the conclusion of safeguards agreements and APs, and the amendment or rescission of small quantities protocols (SQPs). The status of safeguards agreements and APs as of 31 December 2021 is shown in Table A6 in the Annex to this report. During 2021, a CSA with an SQP and an AP entered into force for Eritrea. A CSA with an SQP entered into force for the Federated States of Micronesia. An AP was signed and entered into force for Zimbabwe. Another AP was approved by the Board of Governors for Sierra Leone. SQPs were amended for Belize, Brunei Darussalam, Maldives, Saint Lucia and Sudan, and SQPs were rescinded for Malta and the United Arab Emirates. In 2021, the Director General sent letters to non-nuclear-weapon States party to the NPT that had not yet concluded or brought into force CSAs in connection with the NPT, calling upon them to do so. He also sent letters jointly with the Secretary General of the Inter-Parliamentary Union to parliament speakers of those States Parties, seeking their support to this end. Additionally, the Director General sent letters to States with CSAs but without APs, encouraging them to conclude and bring into force APs to their CSAs. In these letters, he also reminded relevant States with original SQPs of his earlier calls for amendment or rescission of the SQPs. At the end of 2021, 96 States with CSAs in force had operative SQPs, of which 70 SQPs were based on the revised standard text, and 10 States had rescinded their SQPs. In April 2021, the Secretariat held a Technical Meeting focused on its efforts to strengthen safeguards implementation in States with SQPs.

Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)

Until 23 February 2021, the Agency, in light of United Nations Security Council resolution 2231 (2015), continued to verify and monitor the nuclear-related commitments of the Islamic Republic of Iran (Iran) under the Joint Comprehensive Plan of Action (JCPOA). From 23 February 2021 onwards, however, this was seriously affected following Iran's decision to stop the implementation of those commitments, including the AP. During the

Director General Grossi at a press conference with Vice President and President of the Atomic Energy Organization of Iran, Mohammad Eslami, on 12 September 2021.

year, 4 quarterly reports and 30 reports providing updates on developments in between the issuance of the quarterly reports were submitted to the Board of Governors and in parallel to the United Nations Security Council entitled *Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015).*

Islamic Republic of Iran

During 2021, the Agency continued its efforts to engage Iran in order to clarify and resolve the issues related to the presence of nuclear material particles of anthropogenic origin at three undeclared locations in Iran, and the issues related to a fourth undeclared location in Iran. The lack of progress in clarifying the Agency's questions concerning the correctness and completeness of Iran's safeguards declarations seriously affected the Agency's ability to provide assurance of the exclusively peaceful nature of Iran's nuclear programme. The Director General submitted four reports to the Board of Governors entitled *NPT Safeguards Agreement with the Islamic Republic of Iran*.

Syrian Arab Republic (Syria)

In August 2021, the Director General submitted a report to the Board of Governors entitled *Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic*. The Director General continued to urge Syria to cooperate fully with the Agency in connection with all unresolved issues.

Democratic People's Republic of Korea (DPRK)

In August 2021, the Director General submitted a report to the Board of Governors and the General Conference entitled *Application of Safeguards in the Democratic People's Republic of Korea*. In 2021, no verification activities were implemented in the field, but the Agency continued to monitor developments in the DPRK's nuclear programme and to evaluate all safeguards relevant information available to it. The Agency has not had access to the Yongbyon site or to other locations in the DPRK. The continuation of the DPRK's nuclear programme is a clear violation of relevant United Nations Security Council resolutions and is deeply regrettable.

State-level safeguards implementation

The Agency continued to enhance the consistency and effectiveness of safeguards implementation at the State level through a project aimed at improving the development and implementation of State-level safeguards approaches (SLAs) using a structured approach. In September, the Secretariat held a Technical Meeting on improving consistency in the implementation of SLAs. During 2021, based on updated internal procedures and guidance, the Agency continued to update SLAs for States with the broader conclusion.

Cooperation with State and regional authorities

In 2021, the Agency conducted, virtually and in-person, 16 international, regional and national training courses, including courses with counterparts in Japan, the Republic of Korea, the Russian Federation and the United States of America. In total, more than 200 experts from some 50 States were trained on safeguards-related topics, including two courses specifically for States with SQPs. In 2021, each of the seven States participating in the IAEA Comprehensive Capacity-Building Initiative for SSACs and SRAs (COMPASS) began implementing a workplan developed by the Agency and the relevant State authorities.

Safeguards equipment and tools

The passive gamma emission tomography system was routinely used by inspectors to verify damaged fuel assemblies transitioning to dry storage. The Agency successfully qualified a new passive seal that will now be introduced as a replacement for the traditional E-CAP metal seal. In parallel, the development of a new active seal progressed according to plan.

Safeguards analytical services

In 2021, the Agency collected 705 nuclear material samples, 473 environmental samples and seven heavy water samples that were analysed by the Agency's laboratories in Seibersdorf and through the Network of Analytical Laboratories. The Environmental Sampling Environment Enhancement (ESEE) project to modernize and integrate the environmental sampling database and modelling/evaluation tools was initiated in 2021.

Developing the safeguards workforce

In 2021, the Agency conducted 49 distinct safeguards training courses (as some were held more than once, a total of 89 training courses were provided overall), helping to provide safeguards inspectors, analysts and support staff with the necessary core and functional competencies. Seven courses on industrial safety were held in 2021.

Preparing for the future

In 2021, Member State Support Programmes (MSSPs) remained essential to enabling the evaluation, design, testing and preparation of new safeguards technologies to address new verification challenges. A new MSSP was established for the first time since 2013 — the Swiss Support Programme. To further broaden the support base for Agency safeguards, the Agency also forged new partnerships by signing Practical Arrangements with five 'non-traditional' entities.

Safeguards Traineeship Programme — Preparing the Next Generation

The Agency has provided support and assistance to States to help strengthen the capacity of their State systems of accounting for and control of nuclear material (SSACs) for over 45 years. The Agency ran its first training course in 1976. Since then, the Agency has expanded its offering to include a broad curriculum of international, regional and national courses, including e-learning and the provision of Service Series guidelines, as well as conducting such training in-country, for example through advisory missions. In 2021, the Agency trained over 200 participants from 50 countries through 16 courses, focused webinars and one-on-one sessions. Today, there are over 1000 participants enrolled in the Agency safeguards e-learning courses available on the Agency's learning management system, CLP4NET.

The Safeguards Traineeship Programme, established in 1983, has trained a total of 148 young professionals from States with few or no nuclear fuel cycle activities on the various elements of the Agency's work, including safeguards. This ten-month programme provides participants with the opportunity to expand their knowledge, gain practical experience, exchange ideas and, importantly, build a strong collaborative spirit with

their peers. Many of the trainees return to work in their national authorities, in the area of safeguards, or in nuclear-related topics; some also go on to later become safeguards inspectors at the Agency.

In 2019, the Agency decided to offer this programme annually; then, in November 2020, the Director General increased the programme's capacity by extending the offer from three to nine participants every year, starting in 2021.

Owing to the programme's size, focus and intensity, the participants are able to benefit from hands-on activities, including visits to facilities, supervised practical experience within the Department of Safeguards, and mentoring throughout their research work. In 2021, thanks to extrabudgetary and in-kind support from several donors, nine young professionals from Angola, Indonesia, Jordan, Malaysia, Saudi Arabia, Senegal, Sri Lanka, Tunisia and the United Arab Emirates successfully completed the programme. These individuals are now prepared to further the peaceful applications of nuclear energy, either through work in their home countries or in the broader international community.

To further support and assist States to strengthen their SSACs, in 2021, the Agency hosted a pilot two-week SSAC seminar for mid-career professionals, as part of the COMPASS initiative, for seven individuals from COMPASS participant States who are already working in their national authorities.

The Director General meets participants in the 2021 Safeguards Traineeship Programme.

MANAGEMENT OF TECHNICAL COOPERATION FOR DEVELOPMENT

The Technical Cooperation Programme in 2021

The technical cooperation programme is the major vehicle through which the Agency transfers nuclear technology to Member States and builds their capacities in the peaceful use of nuclear science and technology. In 2021, the Agency provided support and assistance to Member States through almost 1600 national, regional and interregional technical cooperation projects.

In 2021, health and nutrition accounted for the highest proportion of actuals (disbursements) delivered through the programme, at 26.2%. This was followed by food and agriculture at 24.2% and by nuclear knowledge development and management at 21.3%. By the end of the year, financial implementation of the Technical Cooperation Fund stood at 84.1%.

In November, the Board of Governors approved 568 new project designs for the 2022–2023 technical cooperation programme cycle. The new projects align with relevant Country Programme Frameworks (CPFs), national sectoral plans, and with regional priorities. Implementation of the new cycles began in January 2022.

Eighteen CPFs, for Burundi, the Czech Republic, Djibouti, Egypt, Ghana, Madagascar, Malawi, Mali, Marshall Islands, the Niger, Palau, Portugal, Saint Vincent and the Grenadines, Singapore, Slovakia, the United Arab Emirates, Uzbekistan and Zambia, were signed in 2021, bringing the total number of valid CPFs to 116 by the end of the year.

Support to Member State efforts to address the COVID-19 pandemic

The Agency continued to support the efforts of Member States to combat the COVID-19 pandemic under interregional project INT0098, 'Strengthening Capabilities of Member States in Building, Strengthening and Restoring Capacities and Services in Case of Outbreaks, Emergencies and Disasters'. To date, 129 countries and territories have requested Agency assistance, with 305 laboratories and institutions receiving technical cooperation support. Shipments include reverse transcription–polymerase chain reaction (RT–PCR) and diagnostic kits and related items. INT0098 is the largest project in the history of the technical cooperation programme, with over €27.8 million in funding from extrabudgetary contributions.

In 2021, additional requests for support to address COVID-19 were received from 11 countries and territories. The Agency responded with the delivery of 20 RT–PCR kits and related equipment, with Samoa and Suriname receiving assistance for the first time. The series of webinars to support COVID-19 testing laboratories, with iterations in Arabic, English and Russian, continued in 2021. Recordings of relevant training material, webinars and educational videos were placed on the Agency's Human Health Campus web site.

To identify the impact of the assistance and its sustainability, the Agency issued a survey to all laboratories receiving assistance. Of the responding laboratories, 13% had no PCR machine apart from that supplied by the Agency. Around 84% (over 50% of which were in low and lower middle income countries) confirmed that the emergency assistance package provided by the Agency could cover the initial gap in testing needs, and 92% acknowledged that Agency support had enhanced their ability to detect COVID-19 and other pathogens, or to provide such services.

Additionally, 92% of laboratories confirmed that they would be able to continue to provide testing beyond the initial Agency assistance. The remaining 8% reported challenges in continuing testing, owing to current global difficulties in procuring laboratory reagents and consumables. Estimates from the survey data received indicate that, as of end December, the laboratories that received Agency assistance were able to provide testing services to over 30 million people.

Overview of Regional Activities

Africa

In 2021, the technical cooperation programme provided assistance to 45 Member States in Africa, of which 26 are least developed countries. Approximately 80% of this assistance was delivered in the key areas of food and agriculture, human health and nutrition, radiation safety and human resource development. This is in line with the main priority areas of the region as described in the CPFs of individual Member States, the African Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (AFRA) Regional Strategic Cooperative Framework (2019–2023) and the Regional Programme Framework for Africa (2019–2023).

In Zimbabwe, a technical cooperation project supported the establishment of an artificial insemination centre — a priority project for the Government of Zimbabwe — under the auspices of the Central Veterinary Laboratory. This new facility, a bull semen collection and processing centre in Mazowe, has the capacity to produce well over 10 000 straws of high value bovine semen per month.

The technical cooperation programme supported training for 48 candidates as radiation protection officers through two Postgraduate Educational Courses (PGECs) in Radiation Protection and the Safety of Radiation Sources for English and French speaking African countries in Accra, Ghana, and Rabat, Morocco, from November 2020 to March 2021. The candidates will work in national regulatory authorities to ensure the safe and secure use of radioactive sources in Africa.

In July 2021, four radiopharmacists graduated with master's degrees in radiopharmacy from the first French-language master's academic programme in radiopharmacy, held in Rabat, Morocco, and supported through a regional technical cooperation project. All four graduates are the first radiopharmacists in their countries. Four more radiopharmacists received support from the technical cooperation programme to complete their master's degrees in radiopharmacy in South Africa, the African Association of Radiopharmacy was established, and e-learning training modules were developed for a postgraduate academic programme in radiopharmacy. In addition, 11 candidates were trained in nuclear electronics, and on the principles, operation and repair of medical and nuclear instruments.

Asia and the Pacific

In 2021, the technical cooperation programme in Asia and the Pacific enhanced the capabilities of 37 Member States and territories, including 7 least developed countries and 6 small island developing States, in the areas of food and agriculture, human health and nutrition, radiation and nuclear safety infrastructure, and water and the environment.

In view of the ongoing COVID-19 pandemic, training and education programmes for technical cooperation counterparts were delivered mainly through virtual webinars and web-based expert sessions. The 'Supporting Women for Nuclear Science Education and Communications (W4NSEC)' training course organized in cooperation with the Australian Nuclear Science and Technology Organisation, and the virtual Nuclear Science and Technology Education Exhibition for secondary school students and teachers, both supported through regional technical cooperation projects, highlighted education initiatives by the Agency.

In-person, long term fellowship training continued; for instance, three students started PhD programmes in radiation disaster medicine at Hiroshima University. An Arabic language version of the PGEC in Radiation Protection and the Safety of Radiation Sources began in November in Jordan.

The virtual Nuclear Science and Technology Education Exhibition highlighted Agency education initiatives.

Europe

The technical cooperation programme assisted 33 Member States in Europe and Central Asia in identified priority areas, focusing mainly on capacity building in nuclear and radiation safety and human health.

Due to the ongoing pandemic, it was not possible to carry out many of the planned hands-on training courses in the field of radiation medicine. However, some 540 medical practitioners in Europe and Central Asia were provided with continuous learning opportunities through virtual training courses on specialized topics.

In Europe and Central Asia, at least 280 aspiring radiation protection professionals received training in English and Russian through PGECs. (Photograph courtesy of International Sakharov Environmental Institute.)

Young professionals participate in practical exercises and demonstrations during a PGEC. (Photograph courtesy of International Sakharov Environmental Institute.)

Following five months of training and studies, 12 young professionals from the region completed a comprehensive PGEC in Radiation Protection and the Safety of Radiation Sources. The course, delivered in Russian, took place from January to July 2021 and was hosted by the International Sakharov Environmental Institute of the Belarusian State University.

In the second half of 2021, the Secretariat called on Member States to support development of the Europe Regional Profile 2022–2027. A working group of National Liaison Officers was established to draft the new document, which is expected to be adopted in 2022.

Latin America and the Caribbean

In 2021, the Agency provided technical assistance to 31 Member States in the Latin America and the Caribbean region, primarily focusing on human health, radiation safety, food and agriculture, and water and the environment.

In August, authorities from the Andean community — Bolivia, Colombia, Ecuador and Peru — approached the Agency for assistance to address Fusarium wilt disease (tropical race 4 or TR4), which affects banana plantations and threatens the nutrition and food security of millions of people worldwide. The Agency, through the technical cooperation programme and the Joint FAO/IAEA Centre, formulated an action plan to combat the spread of Fusarium wilt disease. The first coordination meeting was held in Peru in October 2021. Regional experts assessed stakeholder roles and actions for combatting the disease. An interregional technical cooperation project was also established to address the issue from a long term perspective.

A Regional Steering Committee was established in 2021 to begin implementation of the 2020–2026 Regional Strategic Framework for technical cooperation with Caribbean Community member countries. The Committee will work with the Agency to initiate cooperation activities in the areas of safety, marine environment, food safety and radiation medicine.

The Director General addresses the 22nd meeting of the Board of ARCAL Representatives at a side event during the 65th regular session of the Agency's General Conference.

Emergency Response

The technical cooperation programme is flexible and agile, enabling it to react quickly to unforeseen Member State needs. In 2021, following the X-Press Pearl container ship disaster off the coast of Colombo, Sri Lanka, the Agency enhanced national capabilities to conduct field investigations, procured analytical equipment and provided expert advice for monitoring post-spill contamination and environmental impact. Diagnostic and sequencing kits helped Bangladesh, Cambodia, Indonesia, Myanmar, Nepal, Sri Lanka, Thailand and Viet Nam tackle an outbreak of lumpy skin disease, and a mission to support nondestructive testing was delivered on-site for reconstruction efforts in Lebanon.

The eruption of La Soufrière volcano in Saint Vincent and the Grenadines and a magnitude 7.2 earthquake in Haiti resulted in widespread destruction. The Agency is assisting Saint Vincent and the Grenadines through the procurement of a computed tomography scanner, a mammography unit, equipment for radiation detection, water quality analysis and COVID-19 testing equipment with the financial contributions of partners. In response to Haiti's request, the Agency provided four portable X ray systems to ensure timely diagnosis of the population in affected areas.

Programme of Action for Cancer Therapy (PACT)

The Agency, jointly with the International Agency for Research on Cancer (IARC) and WHO, supported Member States by assessing cancer control capacities, facilitating expert advice for national cancer control planning, assisting with strategic document development, and mobilizing resources for cancer related projects.

Cancer control assessments (imPACT Reviews) were conducted jointly with IARC and WHO in the Democratic Republic of the Congo, Iraq, Nepal and Uruguay, as well as follow-up missions on the implementation of recommendations in Honduras and Jamaica. Additional imPACT Reviews were initiated in Colombia, the Syrian Arab Republic and Uzbekistan. The Agency led support for the preparation of comprehensive national cancer control plans (NCCPs) in ten countries, and contributed significantly to WHO-led support

for NCCP preparation in an additional country. Bangladesh, Liberia, Mozambique, Sierra Leone and the United Republic of Tanzania received assistance to develop bankable documents. Workshops enabled Member States to share good practices in cancer control efforts.

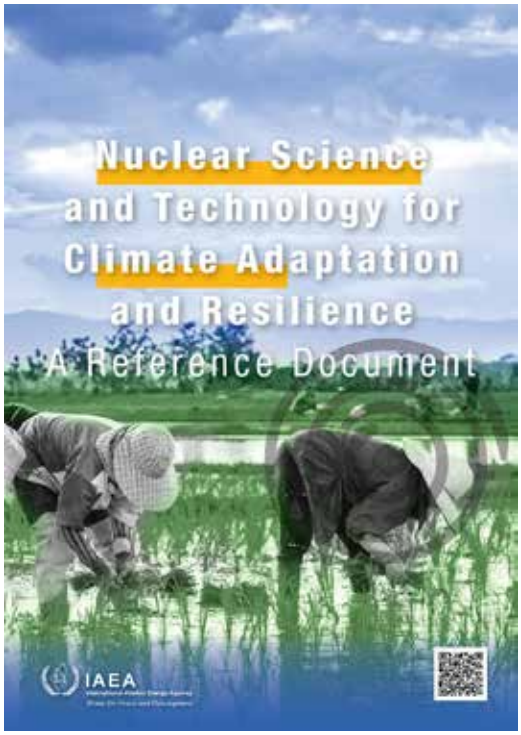
The Agency collaborated with the City Cancer Challenge foundation to increase access to radiation medicine for cancer care.

Technical Cooperation and the Global Development Context

The Agency engaged in several key global events in 2021, with a strong emphasis on climate, including the Climate Adaptation Summit in January and COP26 in November. A blog post drafted by the Agency on climate-smart agriculture was published on the United Nations Framework Convention on Climate Change web site. Agency side events at COP26 included one focused on the contribution of nuclear science and technology to climate change adaptation, and on climate and oceans.

The Agency, in partnership with the Food and Agriculture Organization of the United Nations (FAO), organized a side event at the United Nations Multi-stakeholder Forum on Science, Technology and Innovation for the Sustainable Development Goals (SDGs), entitled 'From COVID-19 Emergency Response to Integrated Action to Address Zoonotic Diseases'. A side event at the United Nations High-Level Political Forum on Sustainable Development in July, 'Nuclear Science and Technology in Support of Integrated Actions to Enhance Countries Post-Pandemic Recovery', presented the role of nuclear applications in supporting food security and improving access to water, and contributed to Agency events in the run up to COP26. The Agency also participated in a panel discussion with the World Food Programme and the United Nations Population Fund on the margins of the United Nations General Assembly, which focused on the COVID-19 response and approaches to strengthening health systems.

The Agency participated in the United Nations Department of Economic and Social Affairs Second Open Call for SDG Good Practices and Success Stories, both as part of the inter-agency team of experts from 24 United Nations entities reviewing the submissions of



A reference document on the role of nuclear science and technology in climate adaptation and resilience presented COP26 attendees with an overview of the Agency's work in this area.

SDG Good Practices, and through the submission of seven SDG Good Practices related to the Agency's support to Member States in a variety of areas.

Legislative Assistance

Country specific bilateral legislative assistance was provided to seven Member States through written comments and advice on drafting national nuclear legislation. Three regional and sub-regional workshops on nuclear law were held for English speaking Member States in Africa and the Caribbean and Latin America and for French speaking Member States in Africa. Further, 12 virtual activities on nuclear law were held as an on-line alternative to some in-person activities and as a follow-up to reviews of legislation. In addition, a new series of interactive webinars on topical issues of nuclear law was launched. The 2021 session of the annual interregional Nuclear Law Institute (NLI) training event had to be postponed until 2022.

Technical Cooperation Programme Management

Quality assurance activities, reporting and monitoring

In 2021, the Agency conducted a full review of technical cooperation projects proposed for the 2022–2023 technical cooperation programme, applying the updated TC Programme Quality Criteria to support improved project descriptions, logical frameworks and implementation strategies. The quality review adopted a country-portfolio approach, emphasizing the links between technical cooperation project design and CPFs, to align planning and design and reinforce monitoring of intended results.

Monitoring and reporting are key elements of the results based approach of the technical cooperation programme. The submission of Project Progress Assessment Reports (PPARs) provides an opportunity to record progress made by projects towards achieving their outputs and outcomes, and to analyse how well project teams interact and adapt to changes in a timely manner. Following updates to the tools and guidelines, the submission rate of PPARs for the 2020 reporting period increased to 82%, the highest rate ever.

Knowledge management and training were strengthened in 2021. Processes for staff induction, orientation, handover and peer knowledge sharing were improved, with the aim of continuously enhancing the timeliness and relevance of support provided to Member States. Practical guidance on technical cooperation procurement for counterparts and end users, reflecting their roles and responsibilities in the process, was also issued.

Financial resources

The technical cooperation programme is funded by contributions to the Technical Cooperation Fund, as well as through extrabudgetary contributions (of a government cost sharing nature, monetary contributions and contributions in kind). Overall, new resources reached a total of some €110 million in 2021, with approximately €86.4 million for the Technical Cooperation Fund (including assessed programme costs arrears, National Participation Costs and miscellaneous income), €23.5 million in extrabudgetary resources, and about €0.1 million representing in-kind contributions. The rate of attainment for the Technical Cooperation Fund stood at 95.2% on payments and 96.5% on pledges at the end of 2021. Payment of National Participation Costs totalled €0.6 million.

Actuals

In 2021, approximately €81.4 million was disbursed to 146 countries or territories, of which 34 were least developed countries.

MANAGEMENT ISSUES

The Agency and the COVID-19 pandemic

Building on the agile and robust COVID-19 framework developed during the previous year, the Agency continued adapting its working arrangements to the evolving situation in the host country of its Headquarters, which included lockdown periods during which the Agency reduced its physical presence on premises. Business continuity was ensured throughout the year and the Agency continued delivering on its mandate without interruption while ensuring the health and well-being of its staff. This was achieved by leveraging the Agency's information technology (IT) infrastructure and adapting human resources guidelines on working arrangements in accordance with the host Government's guidance. In addition, Agency personnel were able to access the COVID-19 vaccination programme organized by the City of Vienna on behalf of the federal authorities.

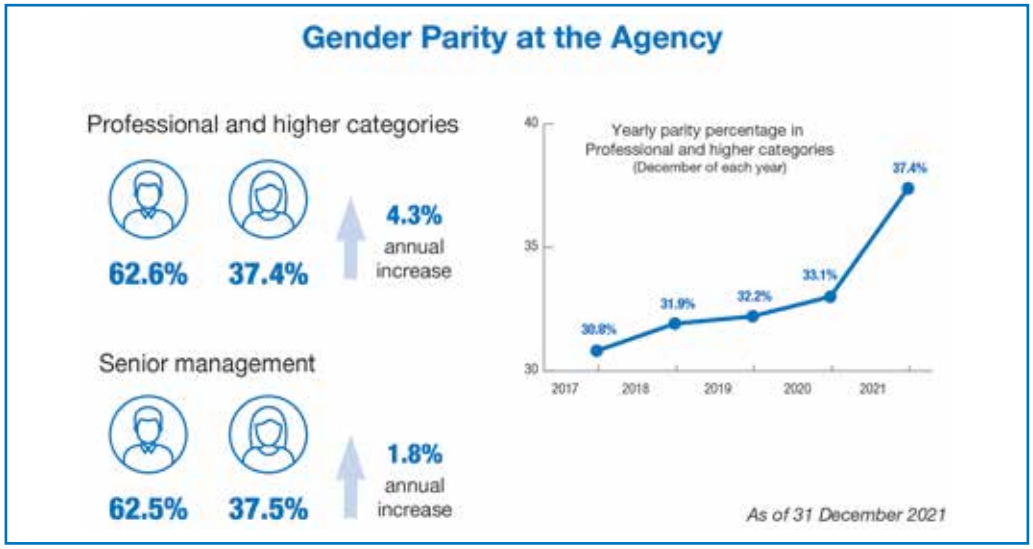
The meetings of the Agency's Policy-Making Organs were organized in either virtual or hybrid format, with simultaneous interpretation and in full adherence to the governing rules and procedures, as well as to the relevant health related guidance. The 65th regular session of the General Conference also followed a hybrid model, which resulted in over 1600 participants attending either in person or virtually.

Gender equality

Further to the goal set by the Director General, the Agency continued to strive to achieve gender parity in all levels of the Professional and higher categories by 2025. At the end of 2021, the proportion of women in the Professional and higher categories was 37.4%, the highest to date, and that of women in senior management positions (D level or higher) was 37.5%. These figures represent an increase of 4.3% and 1.8%, respectively, compared with the figures from December 2020.

In 2021, the Secretariat updated its Gender Equality Policy and its internal Gender Action Plan to include new tasks for the 2021–2022 biennium. The Gender Action Plan is an internal roadmap to support the implementation of the Agency's Gender Equality Policy. It elaborates tasks and milestones towards achieving gender balance in the Secretariat, as well as steps to more systematically mainstream gender concerns in programmatic activities.

One of the four objectives of the Gender Action Plan is to promote an enabling environment. To this end, a Respect for Diversity and Anti-Discrimination Policy was promulgated, which also addressed the issue of gender equality. The policy is being reinforced through mandatory orientation training for all staff, in order to promote a respectful workplace and discourage improper behaviour.



Towards More Women in the Nuclear Field: The IAEA Marie Skłodowska-Curie Fellowship Programme

The Marie Skłodowska-Curie Fellowship Programme (MSCFP) aims to encourage women to pursue a career in nuclear-related fields by providing highly motivated female students with scholarships for master's programmes and an opportunity to pursue an internship facilitated by the Agency. It is currently in its second year of implementation. The second round of applications closed in October 2021, resulting in 110 selected students (10 more than in the previous cycle) from 77 Member States studying in 41 countries. The MSCFP's intention is to grow with each selection cycle to ensure that more women have the opportunity to pursue advanced level education in nuclear-related fields each year. The selected students receive scholarships to pursue advanced studies and internships facilitated by the Agency.

In 2021, 24 students completed master's studies under the programme, and several students started internships facilitated by the Agency. The internships take place across Agency technical Departments and at Agency Collaborating Centres, as well as at partner organizations and in industry.

"The fellowship is helping me become the nuclear engineer that I want to be in order to develop a nuclear power option in my country. It shows women all over the world that pursuing a nuclear-related career is possible."

July Reyes Zacarias
a Nuclear Engineering master's student
from the Dominican Republic

"The Fellowship Programme is playing a big role in my future, giving me the opportunity to study nuclear law in Germany with no financial worries. It makes me feel like my future is taken care of through my education."

Hilma Niitembu Naimbale
a Nuclear Law master's student from Namibia

"As a graduate in nuclear engineering, this internship is allowing me to start a career as a young professional in the nuclear field."

Xiaoluo Wang
a 2020 fellow from China,
who is currently
an intern at the Agency

Together for more women in nuclear

Managing for results

The Agency has strengthened its results based approach in its programme commitment to achieving results, as well as in converting inputs into activities and then to results in the most economical and effective way possible. Performance indicators have been further refined to measure programme performance, with a view to ensuring that reporting to Member States is conducted in a more meaningful manner. Results based monitoring has been strengthened through a dedicated mid-year review, using indicators to track actual results against planned results, and providing periodic information on the status of an intervention in relation to targets and expected results. The use of results based techniques and tools, as well as the dissemination of results and lessons learned, is central to the collection, storing, codification, transfer and communication of knowledge generated. The coordination of knowledge management has also been fully integrated into the Agency's results based management framework.

Partnerships and resource mobilization

The Secretariat progressed significantly in seeking new partnerships and resources to enable the Agency to broaden its services provided to Member States. The renewed corporate approach to partnerships and resource mobilization is based on four pillars: strategic dialogue; an enabling environment; strong internal coordination; and consistent communication and reporting. In addition, the initiatives of the Director General, such as the ZODIAC project, NUTEC Plastics and the Marie Skłodowska-Curie Fellowship Programme, played a catalytic role in resource mobilization. Member States and several non-traditional partners responded positively to these initiatives and provided financial support for the Agency's efforts. In addition, Agency assistance to strengthen Member States' capacities for the rapid detection of COVID-19 received significant support.

The Secretariat strengthened its strategic partnerships with other organizations of the United Nations system and other international organizations. Strong partnerships with several national and international professional associations and organizations were expanded to extend the reach and impact of Agency activities, particularly in the areas of training and capacity building. As a result of greater external outreach, extrabudgetary resources received by the Agency amounted to more than €148 million in 2021. This is an increase of 33% for the 2020–2021 period compared to 2018–2019. At the same time, nearly 50 Practical Arrangements and 3 new memoranda of understanding were signed by the Agency.

Information security and technology

The Agency remained vigilant of ongoing cyberthreats as part of its regular IT operations and strengthened its information and IT security through a number of actions, including implementing a new information security management system, preparing for the ISO/IEC 27001 certification of the system managed by the Agency, and increasing anti-malware and security monitoring. In addition, the operational needs of the Agency in the context of the COVID-19 pandemic continued to be supported, including by maintaining expanded remote access capabilities for staff and adapting IT operating models as required.

Multilingualism

In addition to the documents submitted to the Policy-Making Organs, as well as all Safety Requirements and editions of the IAEA Bulletin being issued in Arabic, Chinese, English, French, Russian and Spanish, 32 other publications were issued in languages other than English. These included the translation of several publications in the IAEA Nuclear

Security Series, IAEA Nuclear Energy Series and IAEA Technical Documents series into Arabic, Chinese, French, Russian and Spanish. In 2021, the Agency publications web page was translated, featuring all publications available in each language on the relevant language page.

In 2021, the Agency continued offering regionally targeted (or 'localized') news on its web site (iaea.org) to better serve its audience in Arabic, Chinese, French, Russian and Spanish, which by the end of the year accounted for 17% of overall web traffic. This, along with search engine optimization measures, led to an 18% growth in visitors to the web site compared to the end of the previous year. The Agency maintained the regular publishing of content on its Facebook accounts in Arabic, French, Russian and Spanish, and on its Weibo account in Chinese. Furthermore, the number of followers on the Agency's social media accounts in languages other than English grew by 29% during 2021. Other outreach activities included the production of 8 videos, 13 press releases and 37 interviews with the Director General, Deputy Directors General and Agency experts in languages other than English.

Nuclear Technology

Nuclear Power, Fuel Cycle and Nuclear Science

1401 **on-line training** and **education courses** hosted on **CLP4NET**

34
active coordinated research projects

Participants of IAEA schools trained

188 Nuclear Knowledge Management school

419 Nuclear Energy Management school

2 INPRO
Dialogue Forums

2 473 312
International Nuclear Information System users

3 667 620
unique searches

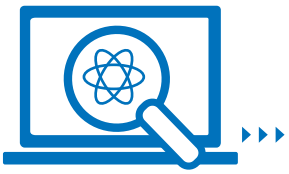
5 670 722
page views

41
publications in 2021

2021

Internet Reactor Laboratory

3 host institutions

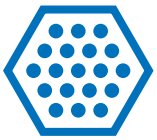


10 guest institutions

17 peer review missions

23 databases

23 modelling tools and simulators



6 IAEA-designated International Centres based on Research Reactors

in **6** countries

meetings

6 new Collaborating Centres

14 active IAEA Collaborating Centres within the Department of Nuclear Energy

Nuclear Power

Objective

To support Member States with existing nuclear power plants to enhance operating performance and safe, secure, efficient and reliable long term operation, including development of human resource capability, leadership and management systems. To support Member States embarking on new nuclear power programmes in planning and building their national nuclear infrastructures, including development of human resource capability, leadership and management systems. To provide methods and tools to support modelling, analyses and assessments of future nuclear energy systems for sustainable development of nuclear energy, and collaborative frameworks and support for technology development and deployment of advanced nuclear reactors and non-electric applications.

Launching Nuclear Power Programmes

In 2021, 26 Member States were considering, planning or implementing a nuclear power programme. The Agency supported them in building awareness of the commitments

required for the decision making process and in the development of the required infrastructure in line with the Milestones approach.

Six virtual (Bangladesh, Ghana, Morocco, Nigeria, Sudan and Türkiye) and one in-person (Egypt) Integrated Work Plan–Country Nuclear Infrastructure Profile meetings were conducted to help establish priority areas for Agency support based on identified needs. The Agency conducted 16 training courses and workshops within the Integrated Nuclear Infrastructure Training programme, with theoretical sessions mostly organized virtually and practical sessions to follow in person.

In addition, the Agency conducted 29 virtual, hybrid and in-person training courses, workshops and expert missions in support of national nuclear infrastructure development. The Agency also organized a webinar entitled 'Experiences of Member States in Building Regulatory Framework for the Oversight of New Nuclear Power Plants' and three webinars as part of the series 'Governing New Nuclear Programmes: Newcomer Success Stories', where experiences and the benefits of Agency support were shared.

The lessons learned from INIR missions were compiled and published in *Integrated Nuclear Infrastructure Review (INIR): Ten Years of Lessons Learned* (IAEA-TECDOC-1947). The Agency also published *Experiences of Member States in Building a Regulatory Framework for the Oversight of New Nuclear Power Plants: Country Case Studies* (IAEA-TECDOC-1948).

Participants in the annual Technical Meeting on Topical Issues in the Development of Nuclear Power Infrastructure, held virtually, discussed challenges and issues in developing infrastructure for the introduction or expansion of nuclear power. At the hybrid 12th Meeting of the Technical Working Group on Nuclear Power Infrastructure, participants made proposals on the further development of guidance and recommendations for new nuclear power programmes based on recent developments and best practices.

Operating Nuclear Power Plants and Expanding Nuclear Power Programmes

The new publication *Application of Wireless Technologies in Nuclear Power Plant Instrumentation and Control Systems* (IAEA Nuclear Energy Series No. NR-T-3.29) provides an overview of the practices, experiences, benefits and challenges in using the technology in instrumentation and control systems of nuclear power plants and other facilities.

(Photograph courtesy of ©Xunxi/Alibaba.)

The new publication *Human Factors Engineering Aspects of Instrumentation and Control System Design* (IAEA Nuclear Energy Series No. NR-T-2.12) emphasizes an interdisciplinary approach for better human–system interfaces and improved human performance in nuclear power plants.

The Agency signed Practical Arrangements with the Nuclear Energy Institute (United States of America) on scientific and technical cooperation on the construction, operation and decommissioning of civil nuclear power plants, as well as with the National Centre for Non-Destructive Testing (Pakistan) on cooperation in non-destructive testing and structural integrity.

The publication *Thermal Performance Monitoring and Optimization in Nuclear Power Plants: Experience and Lessons Learned* (IAEA-TECDOC-1971) describes the essential elements of a thermal performance programme, providing guidelines on the design of the balance of plant systems for new plants and improvements to existing programmes for operating units.

A toolkit was launched to help Member States navigate national and international requirements for supply chain management and quality. A related Technical Meeting on Recent Issues in Supply Chain Management shared experiences, including with regard to the COVID-19 pandemic. The Agency also conducted eight webinars on nuclear supply chain topics, ranging from procurement and management, to counterfeit items, commercial products in safety systems and managing the supply chain in the context of the COVID-19 pandemic.

Human Resource Development and Management and Stakeholder Involvement Support

The Agency published *Systematic Approach to Training for Nuclear Facility Personnel: Processes, Methodology and Practices* (IAEA Nuclear Energy Series No. NG-T-2.8), which includes good practices, recommendations and application examples. In addition, four webinars were conducted as part of the series 'Training and Qualification for Nuclear Facility Personnel'.

The publication *Stakeholder Engagement in Nuclear Programmes* (IAEA Nuclear Energy Series No. NG-G-5.1) provides guidance on developing a stakeholder engagement programme and associated activities. At the Technical Meeting on Stakeholder Involvement, participants discussed Agency outreach products and their adaptation for engaging national stakeholders.

Students and professionals from around the world will benefit from a new Agency Collaborating Centre agreement with the National Institute for Nuclear Science and Technology, France, in the area of education and training in nuclear sciences and applications, nuclear energy, and nuclear safety and security.

Nuclear Reactor Technology Development

The Agency's Open-source Nuclear Codes for Reactor Analysis initiative facilitates an international collaboration framework for the development and application of open-source multiphysics simulation tools to support research, education and training for the analysis of advanced nuclear power reactors.

An Agency webinar on artificial intelligence (AI) entitled 'AI for Nuclear Energy', conducted as part of the International Telecommunication Union's AI for Good Global Summit 2021, drew over 1000 registrations and showcased progress in AI to enhance the development and deployment of nuclear power, paving the way for future activities in this area.

Advanced water cooled reactors

The Agency conducted a Technical Meeting on the Market Readiness of Advanced Nuclear Technologies. Participants discussed evolutionary and innovative nuclear power reactors under development as well as obstacles to their adoption. The Agency published *Hydrogen Phenomena During Severe Accidents in Water Cooled Reactors* (Training Course Series No. 72), which includes an overview of hydrogen risks, analysis, measurement, and mitigation strategies, and focuses on descriptions of hydrogen properties as well as its generation, distribution and combustion.

The Agency concluded a coordinated research project (CRP) entitled 'Methodology for Assessing Pipe Failure Rates in Advanced Water Cooled Reactors' and its results were summarized in a publication *Technical Insights from Benchmarking Different Methods for Predicting Pipe Failure Rates in Water Cooled Reactors* (IAEA-TECDOC-1988).

Small and medium sized or modular reactors, including high temperature reactors

The Agency organized the first Technical Meeting on the Status, Design Features, Technology Challenges and Deployment Models of Microreactors. The event was followed by a high level on-line dialogue with the Director General's participation. The Agency also organized a Regional Meeting on Small Modular Reactors and Microreactors: Design, Cogeneration, Applications, Refuelling Schemes, Transport Options and Deployment Pathways.

The four-year CRP 'Development of Approaches, Methodologies and Criteria for Determining the Technical Basis for Emergency Planning Zone for Small Modular Reactor Deployment', which concluded in 2021, enabled participating Member States to enhance their understanding of adopting appropriate policies for determining the technical basis for emergency preparedness and response arrangements, including emergency planning zones. The results of the CRP will be reflected in a future publication.

The Workshop on High Temperature Gas Cooled Reactor Technology resulted in the transfer of the knowledge base and code package system for high temperature reactors to the Agency from Germany's Jülich Research Centre.

Fast reactors

The publication *Benefits and Challenges of Small Modular Fast Reactors* (IAEA-TECDOC-1972) presents a detailed overview of small modular fast spectrum concepts and highlights their technological, economic and safety features. The Agency also published *Structural Materials for Heavy Liquid Metal Cooled Fast Reactors* (IAEA-TECDOC-1978), which presents summaries of the technical and group sessions, conclusions and recommendations of a Technical Meeting held on this topic, as well as the papers presented at the event.

Participants in the Ninth Joint IAEA–GIF Technical Meeting/Workshop on the Safety of Liquid Metal Cooled Fast Reactors (LMFRs) discussed the harmonization of safety approaches, requirements, design criteria and design guidelines for next generation advanced LMFRs.

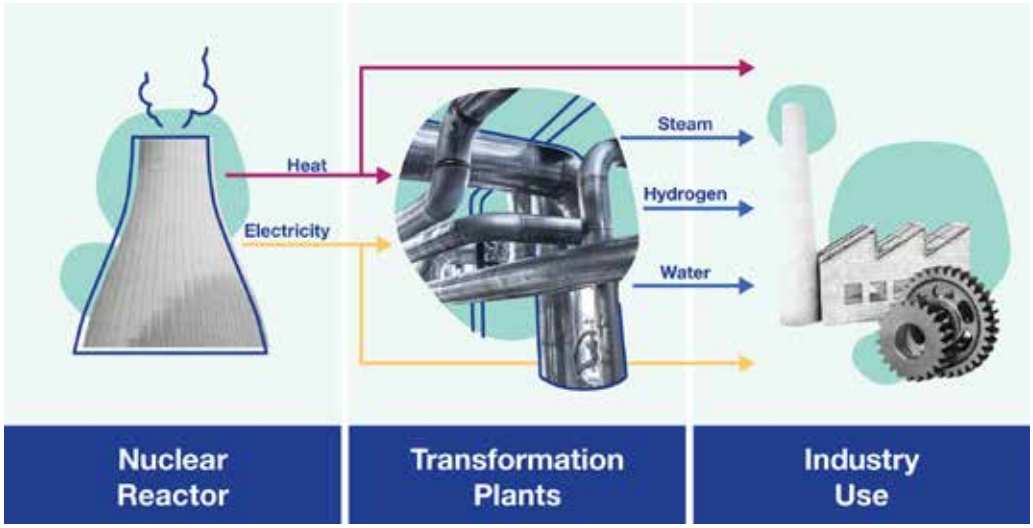
Non-electric Applications of Nuclear Power

The Agency conducted a Technical Meeting on Potential Schemes for Licensing Nuclear Cogeneration Plants, which explored possible regulatory frameworks for cogeneration projects, safety assessment and safety requirements.

The Technical Meeting on the Role of Nuclear Cogeneration Applications Towards Climate Change Mitigation enabled Member States to exchange information on the

potential for nuclear energy to decarbonize their economies and for nuclear cogeneration to help reach their national climate change commitments.

The side event 'Innovations in the Production and Use of Nuclear Hydrogen for a Clean Energy Transition', held during the 65th regular session of the General Conference, highlighted the role of nuclear energy as a provider of both electricity and heat for clean and reliable hydrogen production, offering insights from existing projects and developments in Canada, the Russian Federation and the United States of America. As part of the Webinar Series on Nuclear Technology Breakthroughs for the 21st Century, the Webinar on Nuclear Heat to Decarbonize the Energy Sector showcased available nuclear technologies to support industrial heat applications and underlined that policy makers, end users, stakeholders and society should consider the nuclear option in their efforts to decarbonize industrial processes.



Enhancing Global Nuclear Energy Sustainability Through Innovation

The Agency published *Developing Roadmaps to Enhance Nuclear Energy Sustainability: Final Report of the INPRO Collaborative Project ROADMAPS* (IAEA Nuclear Energy Series No. NG-T-3.22), which documents the scope and outputs of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) collaborative project 'Roadmaps for a Transition to Globally Sustainable Nuclear Energy Systems' (ROADMAPS).

The 18th and the 19th INPRO Dialogue Forums allowed participants to explore the importance of partnerships and cooperation for sustainable nuclear development and deployment as well as the role of institutional innovations in enhancing public acceptance of nuclear power.

The Agency organized the IAEA INPRO School on Methodology, Tools and Analysis for Enhanced Nuclear Energy Sustainability in Thailand and the IAEA–STAR-NET Regional School to Train the Trainers on Nuclear Energy System Modelling and Assessment Using the INPRO Methodology, both held virtually due to the COVID-19 pandemic. Participants received training on the use of various INPRO tools to assess, plan and implement sustainable nuclear energy systems.

CASE STUDY

Poland Contemplates Nuclear Power as Coal Substitute to Meet Climate Goals

In 2021, when reducing the use of coal was a key theme at the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26), Poland advanced its plans to substitute the most carbon-intensive fossil fuel with nuclear energy. The country continues to work with the Agency on developing infrastructure for a safe, secure and sustainable nuclear power programme.

Poland, which generates approximately 70% of its electricity from coal, has plans to build several nuclear power reactors to greatly reduce its reliance on fossil fuel and to meet climate and energy security goals. Two weeks before the COP26 climate summit in Glasgow, United Kingdom, which coincided with the release of the Agency publication Nuclear Energy for a Net Zero World, Director General Rafael Mariano Grossi and Michał Kurtyka, Poland's Minister for Climate and Environment at that time, discussed the country's ambitions for nuclear power.

Speaking as natural gas prices were surging in Europe and other regions of the world, Minister Kurtyka mentioned how the energy crisis would spur more countries to consider nuclear power as part of the solution.

Implementing a nuclear power programme is a complex endeavour — it requires a legislative and regulatory framework and a radioactive waste management plan, as well as broad stakeholder and public support. The Agency supports countries that choose to introduce nuclear power through a range of initiatives, including the Integrated Nuclear Infrastructure Review (INIR) and other peer review services, training and capacity building activities, and advisory services, including for developing relevant management systems

Poland plans to build several nuclear power reactors to reduce its reliance on fossil fuel and to meet climate and energy security goals. The country currently generates approximately 70% of its electricity from coal.

for key organizations. The Agency is also tailoring its assistance to countries through Integrated Work Plans (IWP) and responding in a coordinated manner to national needs for an enabling environment for responsible nuclear power deployment.

Poland in recent years has hosted two INIR missions, as well as several other Agency peer review missions.

"Our nuclear programme foresees that between 6 and 9 GWe will be installed by 2043 in terms of nuclear, which means six reactors, and this will play an extremely important role in replacing the existing baseload capacities based on conventional fuels," Minister Kurtyka said.

Coal and nuclear power plants both produce heat to create steam that drives electricity generating turbines. While coal provides more than a third of global electricity generation, nuclear power is equipped to fill the void resulting from coal plant closures and can provide round-the-clock baseload power in all weather conditions. Baseload power refers to the minimum amount of electric power needed to supply the electrical grid at any given time.

Poland plans to use some of the electricity from its future reactors, as well as from offshore wind farms, to produce clean hydrogen, which can be used to help decarbonize sectors such as industry and transport. The country is also looking into the possibility of deploying high temperature gas cooled reactors, which can improve the efficiency and reduce the cost of producing hydrogen.

In recent years, Poland has hosted an Agency workshop on assessing the environmental impact of nuclear power plants, as well as an IWP review meeting. The country has also taken part in a meeting of the Agency's Technical Working Group on Gas Cooled Reactors, and has hosted other Agency missions, including an Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation, as well as reviews of its regulatory framework and of the safety of its research reactor.

Nuclear Fuel Cycle and Waste Management

Objective

To support Member States in raising awareness and promoting sustainable (safe, secure, effective, innovative) fuel cycle and life cycle management for nuclear energy programmes and nuclear applications users, and contingency planning for a post-incident situation. To support Member States in strengthening their capabilities and human resources, or having access to the best available knowledge, technologies and services.

Uranium Resources and Processing

The new publication *A Preliminary Inventory and Assessment of Uranium Resources in Mine Wastes* (IAEA-TECDOC-1952) provides an initial framework to integrate the goal of comprehensive extraction in the uranium mining industry with environmental and remediation considerations in achieving zero waste.

The Agency published *World Distribution of Uranium Provinces and World Distribution of Thorium Deposits*, also referred to as the 'uranium map' and the 'thorium map', respectively, that display, at a scale of 1:35 000 000, the distribution of uranium and thorium deposits and related resource statistics worldwide.

The 57th Meeting of the Joint OECD/NEA–IAEA Uranium Group was held virtually to coordinate the preparation of the periodic assessment of the global supply of natural uranium and to examine these supply capabilities in relation to the projected demand for natural uranium.

Nuclear Power Reactor Fuel

The new publication *Coolant Chemistry Control and Effects on Fuel Reliability in Pressurized Heavy Water Reactors* (IAEA-TECDOC-1942) presents up to date knowledge on the topic including corrosion phenomena in primary heat transport systems and consequent effects on fuel reliability in pressurized heavy water reactors.

The Agency's *Progress on Pellet–Cladding Interaction and Stress Corrosion Cracking: Experimentation, Modelling and Methodologies Applied to Support the Flexible Operation of Nuclear Power Plants* (IAEA-TECDOC-1960) captures the conclusions of a Technical Meeting held in 2019, providing an overview of pellet–cladding interaction and stress corrosion cracking studies, and reports on progress made since the early 2000s.

Participants in the Technical Meeting on the Design, Fabrication and Irradiation Behaviour of Small Modular Reactor Fuels, held virtually, exchanged information on recent experiences in, and future improvements needed for, the development of small

modular reactor fuels and provided input for future Agency publications on this topic.

The First Research Coordination Meeting on Testing, Modelling and Simulations for Accident Tolerant and Advanced Technology Fuels, held virtually, provided an opportunity to assess research plans proposed by participants in relation to the overall objectives of the related coordinated research project (CRP).

Management of Spent Fuel from Nuclear Power Reactors

The new publication *Phenomenology, Simulation and Modelling of Accidents in Spent Fuel Pools* (IAEA-TECDOC-1949) summarizes the results of a Technical Meeting that reviewed the analysis, simulation and modelling of severe accidents in spent fuel pools.

The Agency published *Status and Trends in Pyroprocessing of Spent Nuclear Fuels* (IAEA-TECDOC-1967), which identifies gaps and technologies requiring further development in pyrometallurgical processes applied to spent nuclear fuel recycling.

The publication *Spent Fuel Performance Assessment and Research: Final Report of a Coordinated Research Project* (SPAR-IV) (IAEA-TECDOC-1975) gives an overview of technical issues related to wet and dry storage and summarizes the objectives and major findings of the related CRP.

Radioactive Waste Management

At an Agency Workshop on Waste Management for Fusion, experts developed specific guidelines for radioactive waste management for future fusion demonstration and pilot power plants.

The Agency published *Decontamination Approaches During Outage in Nuclear Power Plants — Experiences and Lessons Learned* (IAEA-TECDOC-1946), which describes new or improved decontamination techniques and processes to reduce radiation exposures and secondary waste during nuclear power plants outages.

The Joint IAEA–ICTP International School on Radioactive Waste Package Performance Testing, held virtually, promoted exchange of experience of low and intermediate level waste performance testing.

The Agency conducted an Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) peer review mission to Ireland. The country had requested this Agency review to fulfil its obligations under Article 14.3 of European Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste.

Management of disused sealed radioactive sources

The Agency continued its support for the management of disused sealed radioactive sources in Colombia, the Congo, Cyprus, Ecuador and Tunisia. The removal of a high activity caesium-137 source from Bahrain was carried out with virtual oversight from the Agency, owing to COVID-19-related constraints.

The Global Radium-226 Management Initiative was launched during the 65th regular session of the General Conference, providing a platform to facilitate contact between donor and recipient countries in addressing issues of existing radium-226 stocks.

Decommissioning and Environmental Remediation

Decommissioning

The publication *Data Analysis and Collection for Costing of Research Reactor Decommissioning: Final Report of the DACCORD Collaborative Project* (IAEA Nuclear Energy Series No. NW-T-2.12) includes a detailed analysis of decommissioning costs for 20 research reactors, with diverse designs and located in various countries. It provides information on unit factors for research reactor decommissioning, and a basis for estimating uncertainties and contingencies and for assessing the impact of decommissioning planning and characterization activities.

The Agency conducted an ARTEMIS review of the Japan Atomic Energy Agency's *Back-end Roadmap*, considering the overall adequacy of all steps in the 70-year decommissioning and waste management programme. A final report identifying good practices, recommendations and suggestions was delivered to the host.

The Agency conducted the fifth international peer review to assist the Government of Japan in the implementation of the revised 'Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1–4'. The review team provided advice on project management, interactions with the public, research and development, and maintenance of infrastructure on site.

The Agency organized the Nuclear Back End Webinar Series, which helped disseminate good practices and lessons learned in decommissioning nuclear facilities, in addressing progress and prospects at the Fukushima Daiichi and Chornobyl nuclear power plants, in costing of research reactor decommissioning, in circular economy principles and in decommissioning within multi-facility sites.

Environmental remediation

The publication *Managing the Decommissioning and Remediation of Damaged Nuclear Facilities* (IAEA-TECDOC-1989) summarizes the outcomes of the Agency-led International Project on Managing the Decommissioning and Remediation of Damaged Nuclear Facilities, and provides guidance for decommissioning and remediating accident damaged nuclear facilities based on case studies and lessons learned.

The Agency delivered ten webinars in collaboration with members of the Network on Environmental Management and Remediation on contaminated site remediation and management of naturally occurring radioactive material, including four working groups (Africa, Asia, Europe and Latin America) addressing regional challenges.

The Agency conducted a Workshop on the Characterization of Radioactively Contaminated Land, which included hands-on training in taking measurements and interpreting results at the Agency's Seibersdorf laboratories (Fig. 1).

FIG. 1. Participants undergo training in sampling during the Workshop on the Characterization of Radioactively Contaminated Land.

CASE STUDY

China Begins Construction of Its First Underground Research Laboratory for High Level Waste Disposal

In 2021, supported by the Agency with over three decades of research, China began the construction of its first underground laboratory for the disposal of high level waste (HLW). It will help determine the area's suitability for future geological disposal of such waste, generated in China's more than 50 operational nuclear power reactors. Scientists will use the laboratory to characterize and assess the geological, hydrological, geochemical and engineering characteristics of the rocks at the site.

HLW can remain radioactive from thousands to hundreds of thousands of years. The internationally accepted solution for its safe and secure long term management is geological disposal in facilities several hundred metres underground.

The Agency has been supporting China in identifying a suitable site for a HLW repository since 1999. The country's strategy for HLW disposal started with laboratory studies and preliminary site selection. In 2021, underground in situ testing started and will continue to 2050. The construction of the disposal facility is planned from 2041 to 2050, assuming the in situ testing confirms the area's suitability.

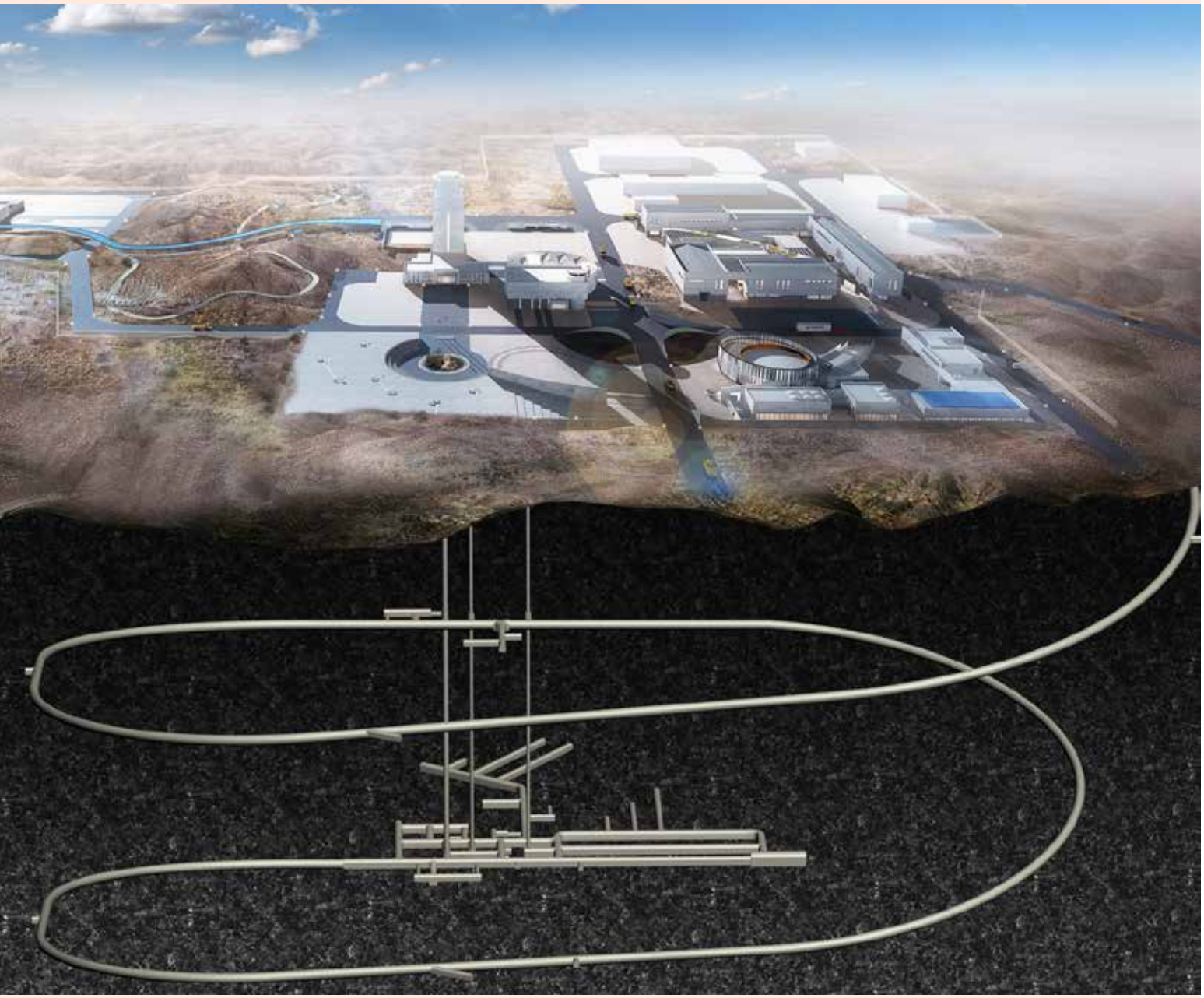
With the Agency's support, 35 Chinese and 11 international experts took part in a six-week virtual expert mission in 2021 to provide input, guidance and recommendations to support plans for the in situ laboratory.

"The construction of an underground research laboratory is an opportunity for advancement in the science and engineering of geological disposal facilities and an essential component in a sustainable energy future for countries," said Stefan Joerg Mayer, Head of the Agency's Disposal Team. "Due to the constraints of the pandemic, we designed, organized and lead an innovative virtual mission to provide expert assistance to China in the construction of this new research and development facility."

The mission took place through a series of 14 on-line, interactive meetings. The experts reviewed and assessed the plans for the construction of the underground research laboratory. They also reviewed the preparations being made for the development of a safety case for the disposal facility as well as for stakeholder engagement.

"The Beijing Research Institute of Uranium Geology (BRIUG) requested the Agency to provide support on characterization of the rock mass, as well as scientific research, prior to the construction of the underground research laboratory," said Petra Salame, Agency Programme Management Officer. "Through this innovative way of organizing the expert mission, we were able to bring together a team of senior experts who addressed a broad range of topics that were proposed by our Chinese counterparts."

The broad range of areas covered resulted in recommendations related to construction, as well as guidance related to the implementation of the laboratory research and development plans during the construction phase.



The underground research laboratory will allow Chinese scientists to fully characterize the site's geology and determine its suitability for a high level waste repository. (Photograph courtesy of the Beijing Research Institute of Uranium Geology.)

Capacity Building and Nuclear Knowledge for Sustainable Energy Development

Objective

To support Member States in strengthening their capacities to formulate robust energy strategies, plans and programmes, and to improve the understanding of nuclear technology's contribution to achieving the Sustainable Development Goals, with an emphasis on mitigating climate change. To support Member States in strengthening their capacities to establish, manage and use their nuclear knowledge base by disseminating knowledge management methodologies, guidance and tools; providing relevant training and service; and fostering international networking. To acquire, preserve and provide Member States with access to information in the area of nuclear science and technology to facilitate sustainable information sharing among Member States.

Energy Modelling, Databanks and Capacity Building

The Agency issued the 41st edition of *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050* (Reference Data Series No. 1), which provides detailed global trends in nuclear power by region. For the first time since the Fukushima Daiichi nuclear accident a decade ago, the high case projections were revised upwards to reflect the potential growth of nuclear power capacity for electricity generation during the coming decades.

The Agency assisted countries in Latin America and the Caribbean as well as in Europe and Central Asia in energy planning for addressing sustainable development needs and climate change mitigation. Particularly, the Agency hosted 26 training events where energy and climate specialists received support in the evaluation of their energy needs and identified ways to satisfy those needs using the Agency's energy assessment tools.

The Agency and the International Renewable Energy Agency were selected as modelling partners for the development of the African Continental Power Systems Master Plan and provided capacity building services and technical support in project implementation for the initiative, led by the African Union Development Agency aiming to establish a long term continent-wide planning process.

Energy–Economy–Environment (3E) Analysis

The Technical Working Group on Nuclear Power in Low-Carbon Energy Systems was launched and held its first meeting resulting in a set of recommendations to the Agency on future activities.

The publication *Financing Nuclear Power Plants* (IAEA-TECDOC-1964) provides details of the experience of Member States recently involved in financing nuclear projects and presents the outcomes of a coordinated research project (CRP) on the same topic. The Agency also published *Assessing National Economic Effects of Nuclear Programmes* (IAEA-TECDOC-1962), which provides a description of the Extended Input Output Model

for Sustainable Power Generation, developed by the Agency, and presents its potential applications. The publication is based on outcomes of a CRP on assessing the national economic effects of nuclear programmes.

As part of the Nuclear Economics Workshop Series organized in cooperation with the United States of America, the Agency conducted a Workshop on the Economics of Emerging Reactor Concepts focusing on cost structures, cost drivers and strategies to reduce the costs of new designs, building on technological innovations and lessons learned from large reactors and other megaprojects. The workshop addressed the role emerging reactor concepts can play in evolving power grids with high shares of variable renewables, as well as policies and strategies that set out what needs to be done to develop an enabling environment for nuclear and other low carbon power generation technologies.

Participants in the Technical Meeting on the Role of Nuclear Energy in Energy Systems with Increased Shares of Variable Renewable Energy Sources discussed long term energy strategies of several Member States and analysed the potential role of nuclear power in future decarbonized energy systems. The event underlined the benefits of the complementarity of nuclear and renewable sources and recommended the need to develop energy modelling methodologies to better represent the complex interactions between generation technologies in low carbon energy systems.

Nuclear Knowledge Management

Two universities received International Nuclear Management Academy (INMA) review missions to assess their progress in developing the INMA programmes, namely Sofia University 'St. Kliment Ohridski' in Bulgaria and the University of West Bohemia in the Czech Republic. The Agency's formal endorsement of the INMA programmes delivered by universities recognizes the quality of the leadership and managerial development content of the programmes delivered. The INMA programme is designed to promote and support leadership and management development for nuclear engineering and nuclear technology graduates, helping them to become competent managers in the nuclear sector.

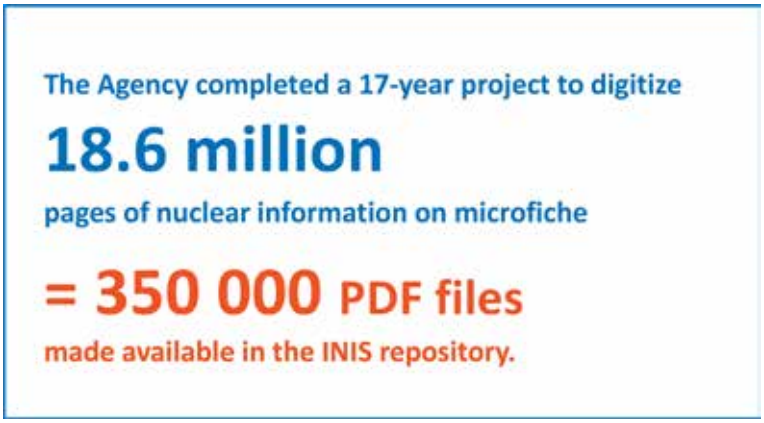
The Nuclear Knowledge Management Digital Hub went live in 2021 on the IAEA CONNECT platform. The digital platform offers easy access for Member States to the latest information on nuclear knowledge management guidance and services to support Member States with operating nuclear facilities and those considering or developing new nuclear programmes.

The new publication *Mapping Organizational Competencies in Nuclear Organizations* (IAEA Nuclear Energy Series No. NG-T-6.14) provides an overview of the range of competencies required to support the development of nuclear organizations. Another new publication, *Exploring Semantic Technologies and Their Application to Nuclear Knowledge Management* (IAEA Nuclear Energy Series No. NG-T-6.15), describes the major digital processes and mapping techniques used to support knowledge management developments in Member States.

Collection and Dissemination of Nuclear Information

The Agency established the Preprint Repository, providing users with Agency publications in advance of their final editing and approval, making them available to the public much sooner than they otherwise would be.

The Agency completed a 17-year project to digitize 18.6 million pages of nuclear information on microfiche. The resulting 350 000 PDF files were made available in the International Nuclear Information System (INIS).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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

In order to innovate in the dissemination of its nuclear data to users, the Agency released a new web tool to plot and download nuclear reaction data. Using a highly efficient interface, experimental reaction data and evaluated reaction data can be plotted and retrieved (Fig. 1).

A joint Technical Meeting with the Jülich Research Centre on tungsten in edge plasmas, held virtually, resulted in the creation of numerical databases required for the development of fusion reactors. Such data are used for computational simulation of the design, with the current focus on simulations/atomistic modelling of plasma and hydrogen interactions with fusion reactor wall material.

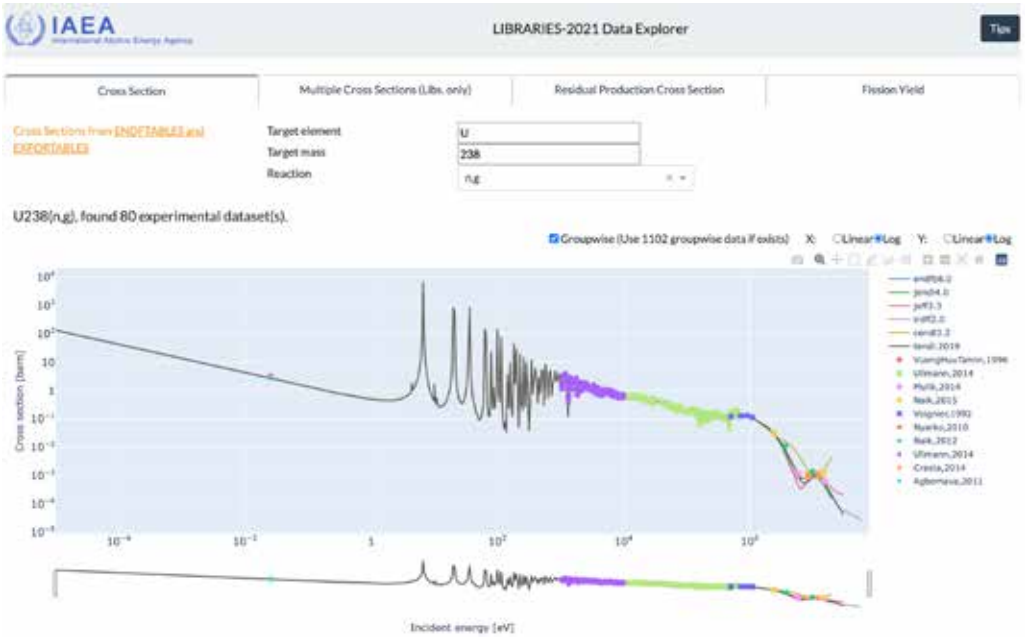


FIG. 1. The Libraries-2021 Data Explorer for retrieval and plotting of nuclear reaction data, using the example of the uranium-238 neutron capture reaction.

Research Reactors

Utilization and applications of research reactors

The Agency published *Neutron Scattering with Low and Medium Flux Neutron Sources: Processes, Detection and Applications* (IAEA-TECDOC-1961), providing up to date technical information on neutron scattering techniques and on instrumentation for neutron scattering, and presenting the main applications of neutron scattering that could be implemented at low and medium flux neutron sources.

The Agency published *Considerations of Safety and Utilization of Subcritical Assemblies* (IAEA-TECDOC-1976), supplementing the Agency safety standards by providing practical information on safety in the design and operation of subcritical assemblies.

At a Technical Meeting on State of the Art Research Reactor Based Radioisotope and Radiopharmaceutical Production, participants provided the latest updates on new and existing facilities and methods to produce radioisotopes and radiopharmaceuticals, including novel ones.

In preparation for the Integrated Research Reactor Utilization Review mission to the RECH-1 research reactor in Chile, requested by the Chilean Nuclear Energy Commission, a Consultancy Meeting, held virtually owing to COVID-19-related restrictions, reviewed the current utilization of RECH-1 and provided advice on the potential and constraints for utilization planning.

New research reactor projects, infrastructure development and capacity building

The Agency published *Specific Considerations in the Assessment of the Status of the National Nuclear Infrastructure for a New Research Reactor Programme* (IAEA Nuclear Energy Series No. NR-T-5.9), which provides a comprehensive means to determine the status of the infrastructure conditions relevant to research reactor projects, and conducted a training

FIG. 2. Hands-on training during the EERRI group fellowship training course.

workshop that provided participants with practical knowledge on application of this Agency-developed methodology.

During the 16th Eastern European Research Reactor Initiative (EERRI) group fellowship training course, held in Austria and Hungary, seven participants received intensive training, including theoretical classes and hands-on exercises at research reactor facilities, covering a broad range of topics related to planning, commissioning, safe operation, maintenance and effective utilization of research reactors (Fig. 2). Overall, the EERRI course has trained 132 participants since 2009.

Research reactor fuel cycle

The Agency published *Research Reactor Spent Fuel Management: Options and Support to Decision Making* (IAEA Nuclear Energy Series No. NF-T-3.9), which provides a comprehensive set of management strategies for research reactor spent fuel and assists in the decision making process for selecting the preferred option for each Member State's situation.

A new coordinated research project was initiated entitled 'Development of Coupled Neutronic and Thermal-Hydraulic Calculational Methodologies for Research Reactors including Analysis and Treatment of Uncertainties', which will allow Member States to improve research reactor modelling and simulation and thus ensure enlargement of the range of usefulness of research reactor facilities without compromising safety.

A Workshop on Dry Storage of Research Reactor Spent Fuel provided participants with detailed information on fuel degradation mechanisms for long term storage, ways of managing such challenges and illustrations of real-world examples of the various approaches to dry storage of research reactor spent fuel.

Research reactor operation and maintenance

A Technical Meeting on Research Reactor Ageing Management, Refurbishment and Modernization allowed Member States to share experiences and lessons learned in improving conditions of reliability, availability and maintainability of research reactors.

At a Technical Meeting on Good Practices for the Operation and Maintenance of Research Reactors, operators, designers and regulators of research reactors discussed and exchanged information and experiences related to good practices in the operation and maintenance of research reactors to further improve their performance, safety and reliability.

Accelerator Applications

By signing a Memorandum of Understanding, the Agency and the United Nations Interregional Crime and Justice Research Institute agreed to increase collaboration in preventing and countering criminal activities around the world using nuclear science and technology. Nuclear analytical techniques provide powerful tools to characterize products subject to counterfeiting and/or illicit trafficking, such as medicines, drugs, food, cultural heritage objects and timber.

The new publication *Sustainability and Self-reliance of National Nuclear Institutions* (IAEA-TECDOC-1943) presents the outcomes of a regional workshop, which addressed the challenges faced by Member States regarding self-reliance and sustainability of their national nuclear institutions.

The new publication *Compact Accelerator Based Neutron Sources* (IAEA-TECDOC-1981) provides an overview of the various types of compact accelerator based neutron source technologies and their applications that are currently available or planned for the future.

Upon request from national accelerator facilities, the Agency conducted five expert missions, one to Algeria, two to Croatia, one to Greece and one to Italy, to assess the

status of the accelerator infrastructure and associated instrumentation, troubleshooting, possible fault correction and repairs. Experts provided advice on effective operation and maintenance as well as utilization programmes of these facilities.

The Agency conducted a joint workshop hosted by the Australian Nuclear Science and Technology Organisation, held virtually, on nuclear and isotopic techniques for cultural heritage. Physicists, materials scientists, chemists, archaeologists, conservators, curators and heritage science stakeholders collected proposals on the application of nuclear and isotopic techniques for cultural heritage, conservation science and archaeology.

Nuclear Instrumentation

A major upgrade and expansion of the interactive worldwide map of X ray fluorescence (XRF) facilities was implemented and made available through the Agency's Nuclear Science and Instrumentation Portal. It now includes the technical and contact details of 1226 XRF laboratories in 116 Member States.

During a joint Agency–Abdus Salam International Centre for Theoretical Physics School on fully programmable systems on chip and their applications for nuclear and related instrumentation, participants familiarized themselves with underlying software design tools and hardware platforms through tutorials and project examples in the field of nuclear applications.

The Agency released through the Cyber Learning Platform for Network Education and Training four hands-on demonstration/training video materials for assisted practical training as well as self-learning resources in support of practices on radiotracer and sealed source methodology and technology as applied to industry and environment.

The Agency organized three advisory meetings, held virtually, with Malaysia, the Philippines and Singapore, where it provided advice and recommendations regarding ongoing national projects using instrumented drones for radiation monitoring and mapping.

Nuclear Fusion

The Agency, in cooperation with the Princeton Plasma Physics Laboratory (United States of America), conducted a Theory and Simulation of Disruptions Workshop, addressing plasma disruptions in tokamaks. Understanding, predicting and mitigating disruptions is one of the principal challenges confronting the ITER project.

Over 450 participants from more than 50 countries participated in the first Agency webinar on fusion commercialization, 'Pushing for Fusion Energy — What is happening now?', and discussed the status of fusion development, as well as examining the potential for public–private collaboration to speed up the process of developing fusion as a future reliable source of energy that is also commercially viable.

The Agency conducted a Workshop on Computational Nuclear Science and Engineering that provided participants with critical skills and tools in mathematical techniques for modelling and simulation of complex systems, high performance computing, and computational methods for processing and analysing large datasets, applied in nuclear science and engineering. Given the high demand for training in this area, the Agency also released a new e-learning course on computational nuclear science and engineering.

The Agency cooperated in the annual International Polytechnic Summer School, jointly organized by the Peter the Great St. Petersburg Polytechnic University (Russian Federation) and the School of Physical Sciences of the Graduate University for Advanced Studies (Japan). In 2021, the school provided students with an introduction to plasma physics and controlled nuclear fusion research and technology, as well as offering a possibility to learn directly from the authors of the contemporary scientific publications contributing to the development of the physics basis for controlled nuclear fusion.

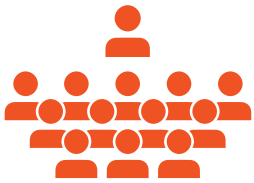
Nuclear Techniques for Development and Environmental Protection

participation in

59 **conferences** and **symposiums**

74

technical, consultancy and **research coordination meetings**



91

active coordinated research projects

20 **webinars**

14 **e-learning modules**

10 **tutorial videos**

22

databases in total

2 new

databases in 2021

OA-ICC News Stream

20 190

unique visitors

2021

Human Health Campus

113 829
users

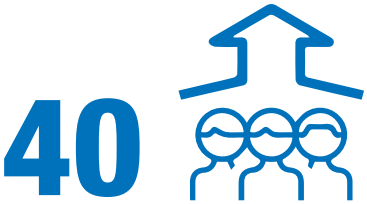
402 112
page views

1133
active research contracts

63
publications

72
guidelines, manuals and protocols

148
external publications



40
active Collaborating Centres
within the Department of Nuclear Sciences and Applications

124
training courses and workshops
with 2579 trainees

Food and Agriculture

Objective

To support Member States in improving efficiency and sustainable intensification of agricultural production and the improvement of global food security through capacity building and technology transfer to Member States. To use nuclear techniques to increase the resilience of livelihoods to threats and crises that impact agriculture, livestock and food security, including climate change, biothreats, food safety risks, and nuclear or radiological emergencies.

Mutation Breeding for Disease Control in Tropical Plants

New outbreaks of plant diseases and pests, and increases in their intensity, have a serious impact on crop production, food security, farmers' incomes and national economies. Tropical race 4 (TR4) of the soil-borne pathogen Fusarium oxysporum, which causes Fusarium wilt, is rapidly spreading in banana production systems globally thereby threatening the banana crop, which ranks among the world's top ten staple foods (Fig. 1).

FIG. 1. TR4-diseased banana plant showing yellowing and wilting of leaves and stem, Guangdong, China.

Following the most recent report of the arrival of this deadly disease in the Andean region in 2021, the Agency responded rapidly by focusing on immediate coordination, capacity building and a holistic approach to combat the disease by targeting genetic diversity and resistance, disease detection, diagnostics and surveillance, and phytosanitary measures.

Another important plant disease of the tropics is coffee leaf rust, which threatens coffee production systems in Mesoamerica. Innovative research in plant mutation breeding at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture has led to the development of resistance screening methodologies, the identification of tolerant or resistant mutants, and the application of techniques that accelerate the breeding process, such as single-cell regeneration and mutagenesis, in coffee. Single-cell mutagenesis, unlike seed mutagenesis, is considered to produce chimera-free plants.

Isotopic Tracing to Identify Sources of Greenhouse Gases from Agriculture

The Agency is developing and validating new methods for the quantification and identification of greenhouse gases in close collaboration with the Institute for Plant Ecology at Justus Liebig University Giessen, Germany (Fig. 2). Greenhouse gas emissions from agriculture account for more than 25% of total greenhouse gas emissions and are generated by numerous microbial processes. The methods to identify the individual production processes involve the use of nuclear techniques and in particular the application of stable isotopes such as nitrogen-15 and carbon-13. The research is pivotal in developing effective mitigation methods for greenhouse gases. Furthermore, some gases such as nitrogen, which play an important role for the nitrogen balance of ecosystems, are very difficult to quantify and require the application of advanced isotopic techniques. The research is essential for a country to be able not only to report on its emission factor, but also to develop effective techniques to ultimately reduce greenhouse gas emissions. As a result of the collaboration with Justus Liebig University Giessen, a comprehensive book on greenhouse gas mitigation

FIG. 2. Soil incubation in a climate chamber in the soil laboratory of Justus Liebig University Giessen, Germany.

methodologies was published aimed at scientists, technical experts and those working in the industry. The book provides practical methods for applying nitrogen-15 tracing techniques to accurately measure nitrous oxide.

Veterinary Laboratory Capacity Building for Surveillance and Early Diagnosis of Zoonotic Diseases

The intensification of farming systems, increased movement of animals due to world trade, and alterations in the geographical distribution of pathogens and their vectors brought about by climate change and variability are impacting the incidence and distribution of transboundary animal and zoonotic diseases, threatening food security, biosecurity and livelihoods. Cost effective nuclear and nuclear derived immunological and molecular diagnostic techniques, including radio- and stable isotopes, are assisting Member States in the identification, assessment and control of endemic, exotic and zoonotic diseases, including those with biothreat potential. In addition, newly developed approaches to veterinary vaccines, including irradiated vaccines, and stable isotopic techniques for tracing and monitoring bird migration are being implemented. Capacities have been enhanced in more than 40 Member States for the surveillance and control of foot-and-mouth disease, avian influenza (Fig. 3), peste des petits ruminants, Rift valley fever, Ebola, African swine fever, lumpy skin disease, trypanosomosis and capripox viruses, and support has been provided to more than 129 Member States for the detection and control of the SARS-CoV-2 virus that causes COVID-19, under the Agency's Zoonotic Disease Integrated Action (ZODIAC) initiative. The Veterinary Diagnostic Laboratory Network (VETLAB Network) continued to provide emergency and routine support to strengthen laboratory capacities for the diagnosis, detection and control of transboundary animal and zoonotic diseases (Fig. 4). In 2021, nearly 600 professionals and technicians participated in several virtual workshops and technical meetings on early detection and characterization of animal and zoonotic pathogens.

FIG. 3. The highly pathogenic avian influenza H5N1 virus can be spread by wild birds.

FIG. 4. Sample collection from wild animals requires high protection and handling standards learned through proper on-site training.

Improvement of the Sterile Insect Technique Package for Human Disease Vectors, Particularly Aedes Mosquitoes

After the outbreak of Zika in late 2015 and early 2016 in Latin America, Member States supported Agency activities to accelerate the development of the sterile insect technique (SIT) and its transfer to field trials as an environmentally friendly technology to control mosquitoes. In the last five years, progress has been made on all components of the SIT package for *Aedes* mosquitoes, leading in 2021 to a significant reduction in the cost of mass production of sterile males through innovative cage and rack designs, and through the development of insect-based diets for mosquito larvae. In addition, procedures for the irradiation of adult mosquitoes were developed. Finally, the handling and transport of male mosquitoes has been improved and drones which allow the release of male mosquitoes in urban environments were developed (Fig. 5).

The unintentional release of female mosquitoes should be avoided as much as possible, as it is the female mosquitoes that transmit the disease. Automatic sex-sorters can help to avoid this risk. The Insect Pest Control Laboratory at Seibersdorf has validated such sex-sorters for several species and strains that were developed by Member States. In addition, researchers produced genetic sexing strains for *Aedes aegypti* by using genes that determine two different eye-colour phenotypes, namely red and white, as selectable markers.

These innovations have been transferred to numerous Member States. Several countries tested or are now testing the technology in field trials, including Brazil, China, Cuba, France, Germany, Greece, Indonesia, Italy, Mexico, Singapore, Spain, Sri Lanka and the United States of America. First successes in reducing human disease transmitting mosquitoes were recorded on a small scale. The collaboration between the Joint FAO/IAEA Centre and the World Health Organization has been strengthened to prepare field tests of the technology against human diseases transmitted by mosquitoes.

FIG. 5. Drone releasing sterile male mosquitoes (Aedes aegypti) on Réunion Island, France.

CASE STUDY

Nuclear Techniques Help the Textile Industry Thrive in Pakistan

Cotton is key to the economy of Pakistan, where the textile industry contributes 8.5% to gross domestic product and accounts for 60% of the country's exports. However, climate extremes such as heat waves and increasing temperatures have taken their toll on cotton, causing an unprecedented fall in yields in recent years.

The Agency, in partnership with the Food and Agriculture Organization of the United Nations (FAO), is working with local experts to develop and introduce new varieties of cotton through plant mutation breeding. This technique uses gamma rays to irradiate cotton seeds and produces new varieties more resilient and better adapted to the new climate reality. New varieties developed in this way account for 40% of all cotton produced in the country, up from just 25% two years ago and 0% in 2016.

"Year on year variation in yields of the cotton crop due to climate change is not only impacting the farming industry negatively, but it is also straining development of the entire cotton-based value chain in the region," said Manzoor Hussain, Deputy Chief Scientist and cotton breeder at the Nuclear Institute for Agriculture and Biology (NIAB). "Agriculture is central to Pakistan's economy, and cotton has a significant role in driving the economy of the country. Through nuclear techniques, we can ensure that this economic area remains profitable."

By harnessing nuclear technology, new cotton varieties tolerant to heat waves and rising temperatures are helping maintain the cotton industry in Pakistan.

The Agency's support and training in plant mutation breeding and selection has helped pave the way for NIAB to release four cotton varieties in the past five years. The popularity of these varieties has been steadily growing.

"I was able to harvest my crop this year with a 30% higher yield than what I could achieve with traditional varieties," said Muhammad Ikram, a farmer from the Bahawalnagar District, 500 km south of Islamabad.

To support the textile industry, which employs 40% of the labour force in the country, the release of new cotton varieties continues. These new varieties have higher yields and improved fibre quality, as well as good agronomic performance and adaptability to climate change variation.

Collaboration between NIAB, the Agency and FAO also includes a long term technology transfer and capacity building programme. The partnership has included training events, workshops and fellowships; training Pakistani scientists in plant breeding techniques focused on developing cotton varieties tolerant to drought and high temperatures.

Through this long-standing collaboration, Pakistani scientists have reached a level of expertise that they can share with specialists in neighbouring countries that are in the early stages of mutation breeding. With this combination of suitable facilities, technical know-how in cotton mutation breeding and improved cotton varieties in the field, NIAB now hosts Agency training for experts from across the region.

Human Health

Objective

To support Member States in enhancing their capability to address needs relating to nutrition and the prevention, diagnosis and treatment of health problems through the development and application of nuclear and related techniques within a quality assurance framework.

Development of the First International Body Composition Reference Charts for Infants Based on Stable Isotopes

To understand infant growth and the associations between early life and later health, it is important to capture the dynamic growth of infants through the assessment of body composition. While height and weight are a core component of early childhood monitoring and global nutrition surveillance, body composition measurements of infants are not widely used due to the lack of available normative data on body composition over the first two years of life. The Agency aimed to address this need through a coordinated research project (CRP) which involved teams from Australia, Brazil, India, Pakistan, South Africa and Sri Lanka. In 2021, using the data generated by this CRP, the Agency developed body composition reference charts based on the stable isotopic technique of deuterium dilution for use in the first 24 months of life (Fig. 6). These charts will enable body composition to be evaluated against international references for children aged 0–2 years, thus ensuring accurate data for improving childhood nutrition monitoring, evaluating interventions to address infant and young child nutrition, and guiding nutrition policy.

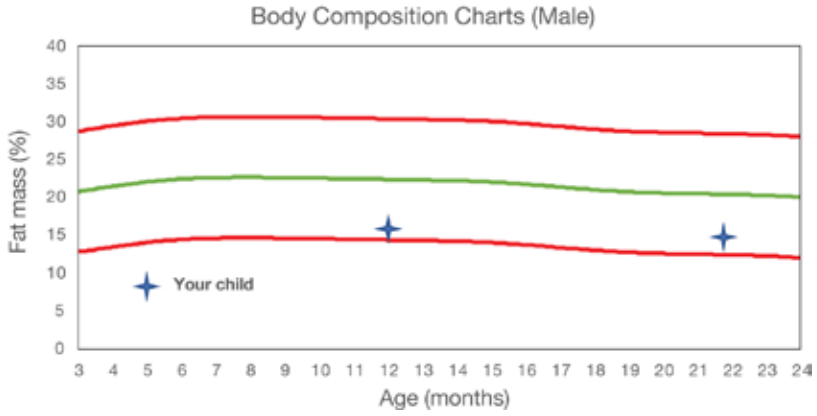


FIG. 6. Example of the body composition international reference chart (fat mass, children 3—24 months, male) based on the nuclear nutrition technique of deuterium dilution.

The Lancet Oncology Commission on Medical Imaging and Nuclear Medicine

The Lancet Oncology Commission report, led and co-authored by the Agency and published in March 2021, highlights the need to improve awareness of, and patient access to, affordable and effective cancer imaging worldwide. It addresses the range of medical imaging modalities, interventional radiology and radionuclide therapies used today, and their uneven availability around the world. The report focuses on the gap between high income countries and low and middle income countries in terms of resources, health system coordination, and education and training. Also outlined is a compelling health economics case for countries, illustrating that scaling up access to nuclear medicine and imaging services would avert nearly 2.5 million cancer deaths worldwide by 2030 and yield global lifetime productivity gains of $1.41 trillion. The Commission calls for an overarching global strategy to address these needs and proposes six actions to enhance access to imaging equipment and to develop a qualified workforce to tackle the disease globally.

Promoting Quality Assurance in Medical Physics Through Guidance and Dosimetry Services

Clinically qualified medical physicists often suffer from a lack of recognition as independent health practitioners. In line with other health professions, medical physicists must obtain certification, and the Agency has published guidelines suggesting pathways to achieve this. The role of the medical physicist includes the development of technical specifications for complex radiotherapy technologies, ensuring that the correct radiation dose is delivered to patients, and the performance of regular quality control of equipment used for diagnosis and treatment (Fig. 7). Jointly with the World Health Organization, the Agency developed technical guidance for Member States on the specifications of radiotherapy equipment packages. The Dosimetry Laboratory introduced a new service to Member States to audit the output of linear accelerator (linac) electron beams, used for the treatment of superficial cancers. Regular quality control of radiographic and mammographic equipment is important to ensure good diagnostic image quality. Radiology services are often unevenly spread geographically and can lack full time specialist attendance. A novel methodology using digital images of simple, inexpensive test objects was published to facilitate remote and automated medical physics review to maintain quality and performance.

FIG. 7. Medical physicists performing a linac electron beam audit.

Water Resources

Objective

To support Member States in using isotope hydrology for assessment and management of their water resources, including characterization of climate change impacts on water availability.

Renewing the Global Network of Isotopes in Precipitation

As climate change becomes a reality, the Global Network of Isotopes in Precipitation (GNIP) has been increasingly used by Member States to track changes in precipitation source regions, interpret palaeoclimatic archives and animal migration pathways, and provide a baseline for forensic verification of crop production. In 2021, the Agency and the World Meteorological Organization (WMO), as host partners of GNIP, signed a renewed Memorandum of Understanding (MoU) at COP26. The MoU will facilitate improved outcomes for the GNIP platform by expanding the network and incorporating advanced data processing and evaluation approaches, particularly in adaptation to and mitigation of climate change. GNIP data were used to construct the Agency's Regionalized Cluster-based Water Isotope Prediction model. This model was expanded in 2021 to globally map naturally occurring tritium in precipitation. The resulting maps depict the spatial distribution of present-day tritium in precipitation and are open access (Fig. 8). They serve as input in addressing the baseline precipitation tritium input function to surface and groundwater systems.

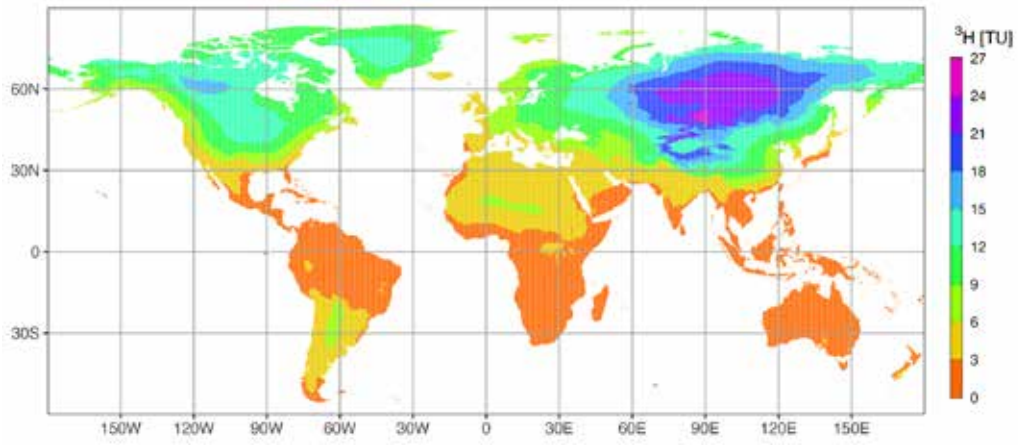


FIG. 8. Contemporary tritium levels in precipitation. TU stands for tritium activity expressed in tritium units.

The Fukushima Prefecture Initiative Project for Improvements in Tritium Analysis

Since the accident at the Fukushima Daiichi nuclear power plant in 2011, there has been continued public interest in better understanding the distribution and environmental dynamics of radionuclides released as a result of the accident. In response to this, the Fukushima Prefecture Initiative Projects (FIP) were established via Practical Arrangements between Fukushima Prefecture and the Agency. In 2016, a new sub-project, the FIP7, was established to improve the analytical capacity of the Prefecture with assistance provided by the Isotope Hydrology Laboratory. During the four years of the FIP7 sub-project, the Agency assisted the Prefecture with installation of a tritium enrichment unit in the Fukushima Prefectural Centre for Environmental Creation as well as comprehensive training on the principles and operation of the tritium enrichment unit, and the Prefecture's scientists are now able to confidently process natural water samples for their tritium analysis (Fig. 9). The project was concluded successfully in March 2021. These activities are essential for the Prefecture to be able to promptly provide independent analytical results to its residents.

FIG. 9. Technical staff from Fukushima Prefecture working on the tritium enrichment system. (Photograph courtesy of the Fukushima Prefectural Centre for Environmental Creation.)

Source Tracking of Water Pollution with Nitrate Isotopes

The integration of nitrate isotope tools with other methods for water quality assessment generates several practical benefits for Member States. Among these are the determination of nitrate sources and the temporal and spatial variability of nitrate in atmospheric, surface and groundwater, as well as the identification of processes controlling nitrate concentrations. In 2021, a new coordinated research project was initiated to examine the relationship between nitrate isotopes and contaminants of emerging concern (CECs). Preliminary work on the Danube River conducted in conjunction with the International Commission for the Protection of the Danube River indicated clear relationships between different groupings of CECs and nitrate isotopes. Twelve projects on all continents will focus on developing guidelines to better understand nitrate source contamination and how nitrate pollution in surface water systems can be better managed.

Environment

Objective

To support Member States in identifying environmental problems caused by radioactive and non-radioactive pollutants and climate change using nuclear, isotopic and related techniques, and to propose mitigation and adaptation strategies and tools. To support Member States in enhancing their capability to develop strategies for sustainable management of terrestrial, marine and atmospheric environments and their natural resources in order to effectively and efficiently address their environment related development priorities.

Beginning the Process for Accreditation of the IAEA Environment Laboratories as a Producer of Environmental Reference Materials Characterized for Gamma Emitting Radionuclides

The Agency has been supporting Member State laboratories by providing reference materials for analytical data quality assurance worldwide since the mid-1960s. Gaining accreditation to underpin laboratory services is an increasing trend in Member States. This is accompanied by an increasing demand for certified reference materials produced by an accredited provider. Therefore, the Agency determined that its IAEA Environment Laboratories should obtain accreditation for reference material production (Fig. 10). For this purpose, a quality management system was established in accordance with international standards. The accreditation initially sought will cover the production of reference materials comprising a selection of environmental matrices certified for activity concentrations of defined gamma emitting radionuclides. The IAEA Environment Laboratories were audited by independent external experts in 2021 and subsequent corrective actions were implemented in a timely manner. The accreditation process is expected to be completed during the first half of 2022.

Support to Sri Lanka to Develop and Implement a Comprehensive and Long Term Programme for Identifying and Monitoring Post-spill Marine Pollution in Coastal Environments

In May 2021, the container ship X-Press Pearl caught fire off the coast of Sri Lanka, and sank, causing enormous environmental damage (Fig. 11). The ship's cargo included highly corrosive and hazardous chemicals, tonnes of oil/lubricants and billions of plastic pellets (nurdles) that have created one of the worst environmental disasters in Sri Lanka's history. Following a request by the Sri Lanka Atomic Energy Board, the Agency began mobilizing emergency support to procure materials and expert virtual assistance to support national efforts to identify, assess and monitor the pollution. The assistance includes the provision

FIG. 10. Reference materials are essential to Member State laboratories in their environmental, climate, radiation and food safety related monitoring and research programmes.

of sampling equipment for microplastics, seawater and sediments; multiparameter meters; and immersion fluorometers to measure the presence of oil in the seawater. Furthermore, the Agency provided marine robotic solutions including underwater remotely operated drones to visually monitor subsurface conditions around the shipwreck; a compact Fourier transform infrared spectrometer to characterize large marine microplastic and plastic debris; and an elemental analyser, to track and understand changes in the marine environment. As a precautionary measure, even though there were no known radioactive substances on board, the Agency is also procuring an underwater in-situ gamma ray spectrometer to help identify, localize and address any radioactivity associated with either the shipwreck or the ship's containers.

FIG. 11. Burned-out wreck of the X-Press Pearl after the sinking of the ship in the shallow waters of Sri Lanka. (Photograph courtesy of the University of Sri Jayewardenepura, Sri Lanka.)

CASE STUDY

Protecting Brazil's Coastal and Marine Ecosystems Using Isotopic Techniques

In late 2021, a red tide event stretched across more than 200 km of Rio de Janeiro's coastline. It lasted more than eight weeks and coloured the clear blue waters a dark, reddish brown, which drove away bathers on the Arraial do Cabo coast. In the high tidelines at the Praia Vermelha beach, dead jellyfish were observed, prematurely assumed by bathers to be related to the effects of the red tide event.

But were they? Support by the Agency has enabled scientists to assist Brazilian authorities in answering this question and to adopt strategies to monitor, mitigate and protect the coastal and marine environments impacted by natural disasters, including red tide events or harmful algal blooms (HABs). The authorities established that the occurrences were due to a widespread HAB event and were able to pinpoint the various species known for forming the micro-algal blooms that caused the changing tides throughout November and December.

To respond to the emergency situation, the Agency trained Brazilian specialists in the use of radioisotopes and stable isotopes and related nuclear techniques through its technical cooperation programme in Latin America and the Caribbean. The Fluminense Federal University in Niterói has been equipped with targeted isotopic and nuclear equipment, and its staff trained on advanced analytical technology, such as X ray fluorescence and elemental and stable isotope fingerprinting techniques.

"The training and equipment provided are helping Brazil to identify triggers and monitor HABs more effectively," said Dominika Zahrer, the Agency Programme Management Officer coordinating the activities with Brazil. The origins of the cooperation date back

Praia Vermelha beach, popular among tourists in the state of Rio De Janeiro, Brazil, where lifeless jellyfish and contaminated water are being left behind. (Photograph courtesy of R. Coutinho/Admiral Paulo Moreira Institute for Sea Studies.)

to when the Fundão tailings dam in Mariana, the oldest city in the state of Minas Gerais, collapsed in 2015, and the disaster left two villages devastated, with 19 lives lost and around 200 homes destroyed, she added.

This support helped characterize and determine the composition of materials and evaluate heavy metal pollution in the estuarine impacted sediments. This enabled Brazilian experts to assess the impact of the Fundão tailings dam burst on coastal and marine environments to help monitor, protect and recover these environments. Their knowledge and equipment have come in handy several times since then, including during last year's red tide event.

"Without the integrated use of stable isotopes and nuclear techniques, it would have been extremely difficult to assess the origin of the pollution and the environmental impact caused by the Fundão dam collapse and now identify the HABs triggers," said Imma Tolosa, research scientist at the Agency. The information produced and disseminated by Fluminense Federal University is allowing the Ministry of the Environment to improve its emergency action plan for protecting fauna, improve water quality and focus on the continuous recovery of the coastal and marine environments.

"We must continue to assess coastal management tools and the long term effects of pollutants, monitor the effectiveness of management actions to reduce further contamination to lakes, bays and the ocean as well as to identify the triggers of HAB events and other pollutants," said Roberto Meigikos dos Anjos, physicist at Fluminense Federal University.

Brazil's coastline is also seeing an increase in oil spills and plastic pollution, which is harming marine life. Techniques similar to those used to identify HABs and assess the dam collapse are now being implemented to increase the resilience of Brazil's coastal ecosystem to pollution, and to develop a course of action to minimize the effects of an oil spill and plastic debris.

Radioisotope Production and Radiation Technology

Objective

To support Member States in strengthening their capability to produce radioisotopes and radiopharmaceuticals. To support Member States in applications of radiotracers and radiation technology for industrial use, environmental remediation, preservation of cultural heritage artefacts and production of novel high performance, environmentally friendly materials for diverse purposes.

New Coordinated Research Project on Production and Quality Control of Actinium-225 Radiopharmaceuticals to Support Local Production in Member States

The main limitation for the wide application of targeted alpha therapy is the availability of suitable radionuclides, as well as approved guidelines and protocols for the production and quality control of these radiopharmaceuticals. In light of advances in the preparation and clinical application of alpha-emitter radiopharmaceuticals, especially actinium-225, a new coordinated research project has been initiated to assist with building capacities for the development, production and quality control of this new generation of therapeutic radiopharmaceuticals focusing on actinium-225 radiopharmaceuticals (peptides, immunoconjugates, small molecules, etc.), addressing quality control, preclinical studies and health regulatory issues — all aspects prior to clinical applications (Fig. 12).

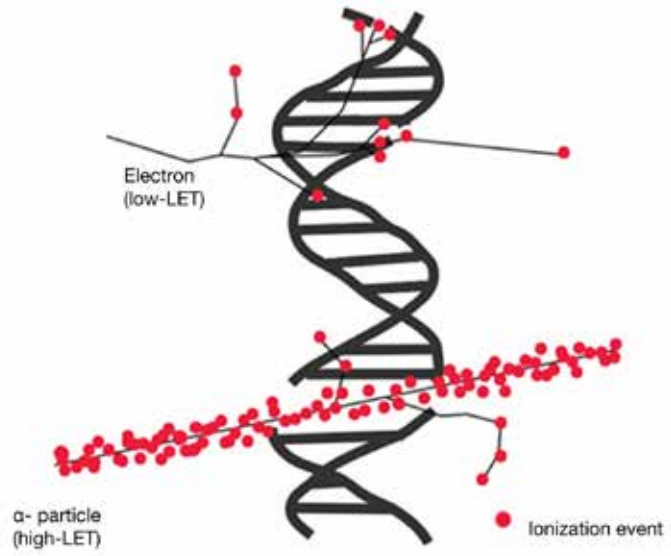


FIG. 12. Comparison of alpha and beta particle effect on target DNA. (Photograph courtesy of the United States Department of Energy.)

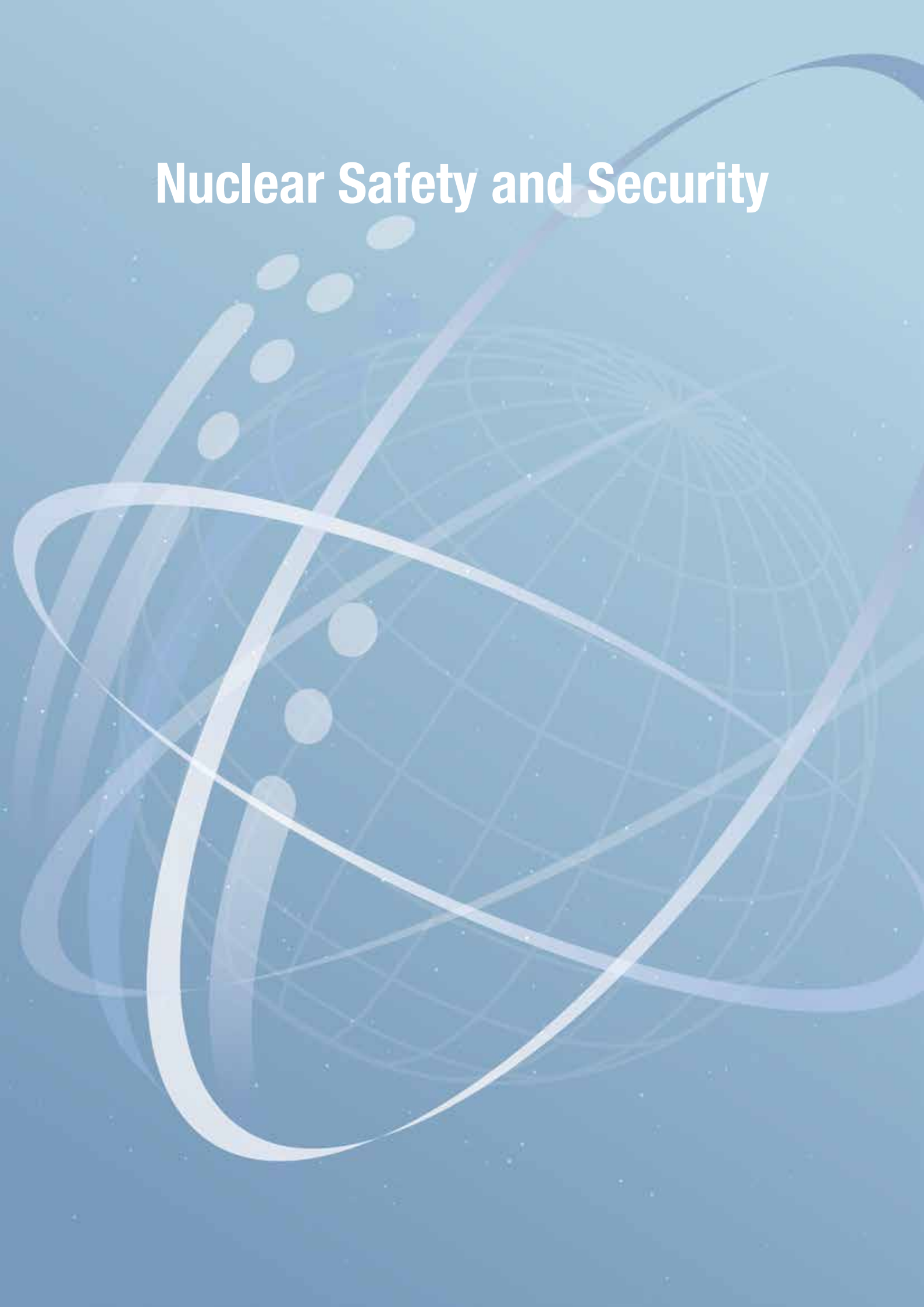
Training and Capacity Building for Member States in Applications of Radiation Technologies

The Agency conducted three training programmes jointly with the Korea International Cooperation Agency, the Korea Atomic Energy Research Institute and the World Council on Isotopes in radioisotope production, radiopharmaceuticals and radiation technology. All three programmes were conducted virtually and benefited participating Member States by advancing technical knowledge and provided networking opportunities with professional peers. These programmes included an e-learning course on diagnostic and therapeutic radioisotopes and radiopharmaceuticals application with 27 Member States; a course on radiation technology and processing with electron accelerators given to senior managers, covering principles and applications of electron accelerators, polymer processing, wastewater or contaminated-air treatment, and sterilization; and a workshop on the establishment of long term management plans by strengthening capacity for diagnostic and therapeutic radioisotopes and radiopharmaceutical applications for ten countries with the aim of strengthening their capacities in establishing long term management plans and guidelines in the field of radioisotopes and radiopharmaceuticals.

The Agency held a School on Radiation Technologies with the World Nuclear University. The course covered various areas of radiation technologies, including medical, industrial and scientific uses of radioactive sources and radiation producing facilities. The School cohort comprised 33 fellows from 18 countries with a wide range of professional experiences, including individuals from regulators, research, academia and industry. The training consisted of lectures, virtual tours and breakout sessions on leadership challenges, public communication challenges and final project preparation.

A School on Non-power Nuclear Applications held jointly with the Rosatom Technical Academy was attended by 21 fellows from 11 countries with a wide range of professional experience and backgrounds. The training included lectures and discussions which covered various areas of radiation technologies, including medical, industrial and scientific uses of radioactive sources, and radiation producing facilities.

Nuclear Safety and Security



Nuclear Safety and Security

343

safety related capacity building events

103

security related training events

3 **international conferences**

1 **ConvEx-3** **exercise**

Physical Protection Upgrades

completed at

1 **nuclear power plant**

3 **research reactors**

31

Safety related peer review and **advisory service missions**

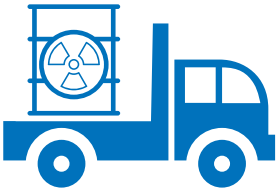
6

security related advisory service missions

2021

120 incidents reported

to the Incident and Trafficking Database



13

IAEA publications issued in 2021

6

IAEA Nuclear Security Series

7

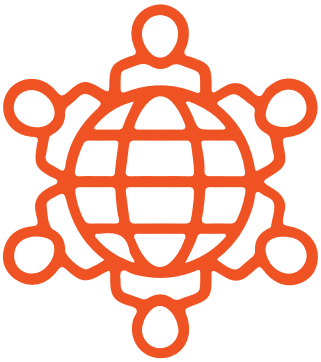
IAEA Safety Standards Series

Convention on Nuclear Safety

2 new Parties **91** total

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

3 new Parties **86** total



Convention on the Physical Protection of Nuclear Material

2 new Parties **164** total

Amendment to the Convention on the Physical Protection of Nuclear Material

2 new Parties **127** total

Incident and Emergency Preparedness and Response

Objective

To maintain and further enhance efficient Agency, national and international [emergency preparedness and response] capabilities and arrangements for effective response to nuclear or radiological incidents and emergencies independent of the triggering event(s). To improve exchange of information on nuclear or radiological incidents and emergencies among Member States, international stakeholders, and the public and media in the preparedness stage and during response to nuclear or radiological incidents and emergencies, independent of the triggering events.

Strengthening Emergency Preparedness Arrangements

In March 2021, the Agency finalized the curriculum for a pilot international master's degree programme in emergency preparedness and response (EPR) based on the Agency's safety standards, to be implemented in Member States to ensure an adequate level of national preparedness and response to nuclear or radiological emergencies. The first university to implement the curriculum was Peter the Great St. Petersburg Polytechnic University, in the Russian Federation, in September 2021.

The Agency organized a Technical Meeting on Next Generation Reactors and Emergency Preparedness and Response in October 2021, where participants discussed, inter alia, how safety improvements may impact emergency arrangements for next generation reactors; challenges in regulating on-site emergency arrangements for these reactors; applicability of specific concepts in EPR described in the Agency's safety standards; and various aspects to be considered when establishing needed emergency arrangements.

Response Arrangements with Member States

The Agency conducted a Level 3 Convention Exercise (ConvEx-3), hosted by the United Arab Emirates (UAE) in October 2021, to test the international arrangements for response to a major nuclear emergency. The two-day emergency exercise tested the response to a simulated accident at the Barakah nuclear power plant (NPP) in the UAE. The exercise also included several firsts: an Agency assistance mission, composed of experts from France, the Republic of Korea, the United States of America and the Agency, was deployed, integrated into the UAE national response and provided radiation monitoring data from the area around the Barakah NPP; 112 laboratories worldwide provided rapid gamma spectrum analysis results, thus testing not only the capability to measure but also the capability to operatively transmit results; and the Agency social media simulator was used and allowed participants to test responses to simulated crises on social media.

Shift turn-over between operations officers during the 36-hour ConvEx-3 nuclear emergency exercise.

ConvEx-2b exercise

29 Member States and

5 international organizations acting as 'Assisting Players'

18 Member States acting as 'Requesting States'

The Agency conducted a ConvEx-2b exercise in March 2021 with the largest number of participants to date, which involved 29 Member States and 5 international organizations acting as 'Assisting Players' and 18 Member States acting as 'Requesting States'.

Response to Events

The Agency presented a report on communicating on events including those with little or no impact on nuclear or radiation safety that may raise public or media interest to the Board of Governors in August 2021. In the report, Member States were strongly encouraged to prioritize a prompt response to queries about relevant events of public or media concern and to consider addressing media queries with promptness and transparency.

In response to requests for assistance from Thailand in 2021, the Agency coordinated its first ever virtual international assistance mission, involving Response and Assistance Network declared capabilities. Response to the event was conducted in accordance with the Agency's emergency response roles.

In-house Preparedness and Response

The Agency organized a comprehensive programme of training classes and exercises to enhance the skills and knowledge of Agency staff members serving as qualified responders in the Incident and Emergency System. The programme offered 142 hours of training during the year, including 71 classes for 191 Agency staff responders. In 2021, 450 external visitors learned about the Incident and Emergency Centre during (partly virtual) presentations and tours of its operational area.

Safety of Nuclear Installations

Objective

To support Member States in improving the safety of nuclear installations during site evaluation, design, construction and operation through the development and maintenance of an up to date set of safety standards and providing for their effective application. To support Member States in establishing and enhancing their safety infrastructure through review services, and in improving the safety of nuclear installations by assisting their adherence to, and facilitating implementation of, the Convention on Nuclear Safety and the Code of Conduct on the Safety of Research Reactors. To support Member States in capacity building through education and training, and by encouraging the exchange of information and operating experience and international cooperation, including enhanced coordination of research and development activities.

Regulatory Infrastructure for Safety

The Agency held a virtual Regional Workshop on Self-Assessment of Regulatory Infrastructure for Safety for Arab Network of Nuclear Regulators Member States in December 2021.

In October 2021, the Agency held a virtual Workshop on the Application of a Graded Approach to Regulating Nuclear Installations in Latin America to provide a platform for discussion and exchange of information, knowledge and lessons learned in applying a graded approach to all the functions of regulatory programmes.

The Agency developed a Technical Report on the safety–security–safeguards considerations by design of novel advanced reactors, including small modular reactors (SMRs). The report elaborates on the gaps and challenges in this area and provides input to a draft Safety Report provisionally entitled *Review of Applicability of Safety Standards to Novel Advanced Reactors*, which is currently under development.

The Agency hosted the virtual Steering Committee Meetings of the SMR Regulators' Forum in April and November 2021, enabling discussions among Member States and other stakeholders to share SMR regulatory knowledge and experience. The Forum's three working groups published multiple reports and began work on selected topics for their next phase. The Agency also held a workshop on the regulatory challenges of SMRs in Amman in December 2021.

Convention on Nuclear Safety

The Agency facilitated the Organizational Meeting for the Joint Eighth and Ninth Review Meeting of the Contracting Parties to the Convention on Nuclear Safety in October 2021, where the Contracting Parties confirmed, inter alia, the Officers for the Joint Review Meeting and the composition of Country Groups.

Press conference during the Integrated Regulatory Review Service follow-up mission to Belarus in December 2021.

Design safety and safety assessment

The Agency published *Level 1 Probabilistic Safety Assessment Practices for Nuclear Power Plants with CANDU-Type Reactors* (IAEA-TECDOC-1977) in September 2021, *Current Approaches to the Analysis of Design Extension Conditions with Core Melting for New Nuclear Power Plants* (IAEA-TECDOC-1982) in October 2021, and *Risk Aggregation for Nuclear Installations* (IAEA-TECDOC-1983) in December 2021.

The Agency held a virtual Technical Meeting on CANDU Probabilistic Safety Assessment in October 2021 to facilitate cooperation and information exchange among the members of the CANDU Probabilistic Safety Assessment Working Group. Also in October 2021, the Agency held a virtual Technical Meeting on the Licensing of Advanced Nuclear Fuels for Water Cooled Reactors.

The Agency published three Safety Guides related to design and safety assessment: *Format and Content of the Safety Analysis Report for Nuclear Power Plants* (IAEA Safety Standards Series No. SSG-61); *Protection against Internal Hazards in the Design of Nuclear Power Plants* (IAEA Safety Standards Series No. SSG-64); and *Equipment Qualification for Nuclear Installations* (IAEA Safety Standards Series No. SSG-69).

The Agency has also continued to conduct Technical Safety Reviews of new build projects and operating plants in several Member States, helping to enhance the nuclear safety justification in areas that may need improvements in accordance with Agency safety standards. The Agency has also developed guidelines for conducting Technical Safety Reviews for conceptual designs.

Safety and protection against external hazards

The Agency held four hybrid Technical Meetings in September, October and November 2021 to share experiences on site evaluation and design to protect nuclear installations against external hazards, and on evaluation of seismic safety for existing nuclear installations and innovative reactors.

Field visit by an operations reviewer during the Operational Safety Review Team mission in November 2021. (Photograph courtesy of Kalinin nuclear power plant.)

The Agency published two Safety Guides: *Seismic Design for Nuclear Installations* (IAEA Safety Standards Series No. SSG-67) and *Design on Nuclear Installations Against External Events Excluding Earthquakes* (IAEA Safety Standards Series No. SSG-68).

Operational safety of nuclear power plants

The Agency published the revised *SALTO Peer Review Guidelines* (IAEA Services Series No. 26 (Rev. 1)) in June 2021.

The Agency finalized the preparation of the Technical Report on experiences of Member States in ensuring safety, security and reliable operation of nuclear and radiation facilities and activities during the COVID-19 pandemic. This publication, prepared jointly with Member States, aims to summarize and share the actions taken by various stakeholders to manage the risks to the continued operation of facilities and activities posed by the pandemic.

The Agency revised and approved plans to publish revisions of the *IRS Guidelines* (IAEA Services Series No. 19) and the *Manual for IRS Coding* (IAEA Services Series No. 20). The Agency published *Ageing Management of Nuclear Power Plants during Delayed Construction Periods, Extended Shutdown and Permanent Shutdown Prior to Decommissioning* (IAEA-TECDOC-1957) in May 2021. The Agency also developed and approved plans to issue two publications related to ageing and long term operation of nuclear power plants provisionally entitled *Ageing Management and Long Term Operation of Nuclear Power Plants: Data Management, Scope Setting, Review of Plant Programmes and Documentation; and Regulatory Oversight of Ageing Management and Long Term Operation of Nuclear Power Plants*.

Integrated Nuclear Infrastructure Review for Research Reactors mission in Thailand in December 2021.

Safety of Research Reactor and Fuel Cycle Facilities

The Agency held a virtual Technical Meeting on the Use of a Graded Approach in the Application of the Safety Requirements for Fuel Cycle Facilities in July 2021, at which participants exchanged experience in the use of a graded approach in the application of safety requirements, including the Agency's safety standards.

The Agency held a virtual Technical Meeting on Safety Analysis and Licensing Documentation for Fuel Cycle Facilities in November 2021.

The Agency held two workshops to assist Member States in the preparation of a feasibility study and assessment of national nuclear infrastructure for new research reactor programmes.

The Agency conducted an Integrated Nuclear Infrastructure Review for Research Reactors mission to Thailand in December 2021 to assess the status of development of national infrastructure to support a new research reactor project.

The Agency provided assistance in reviewing the commissioning programme of a research reactor in the Philippines and held virtual training for the Philippines via live experimental demonstration on a subcritical assembly in the United States of America.

The Agency held four Technical Meetings aimed at assisting participating Member States to build capacity in several safety areas of research reactors. These included Technical Meetings on ageing management, refurbishment and modernization in May–June 2021; on digital instrumentation and control systems for research reactors in August 2021; on good practices for the operation and maintenance of research reactors in August 2021; and on the safety of research reactors under project and supply agreements and review of safety performance indicators in November 2021.

CASE STUDY

Agency Continues In-person Safety and Security Peer Review Services Despite COVID-19 Pandemic

"When the COVID-19 pandemic first caught the world's attention, one of our many concerns was how it would impact the Agency's commitment to supporting high levels of nuclear safety and nuclear security worldwide," said Lydie Evrard, Deputy Director General and Head of the Department of Nuclear Safety and Security. "Our activities were aimed in particular at supporting Member States in their efforts to ensure the safety of nuclear power plants under these unprecedented pandemic conditions. Equally important during this period was to provide support to Member States for them to ensure that radioactive sources and nuclear material were protected against malicious acts."

The Agency's 17 types of peer review and advisory services in nuclear safety and security include the International Physical Protection Advisory Service (IPPAS), which provides advice on how to establish, enhance and maintain the security of nuclear and other radioactive material and associated facilities and activities, using the Nuclear Security Series as the basis; and the Operational Safety Review Team (OSART) service, which helps strengthen the safety of nuclear power plants during both commissioning and operation, based on the Agency's safety standards.

Both services, which require in-person reviews on site, have faced huge challenges owing to the COVID-19 pandemic and related travel restrictions, making the review activities extremely difficult to plan and implement.

Despite these challenges, in 2021, the Agency conducted six IPPAS peer review missions in Belarus, Burkina Faso, the Czech Republic, the Niger, Senegal and Türkiye. This was alongside seven face to face OSART reviews in Belarus, France, the Russian Federation and Slovakia.

As the world continues to grapple with the COVID-19 pandemic, the Agency has ensured its nuclear review services are carried out with minimal disruptions.

IPPAS contributes to nuclear security for a quarter of a century

As part of IPPAS missions, an international team of experts reviews a country's nuclear security regime and compares it with international guidelines and best practices. Over the past 25 years, 96 IPPAS reviews, including 22 follow-up missions, have been conducted in 57 countries.

As a large amount of nuclear and other radioactive material is used globally for peaceful purposes, the Agency is continuing to support the protection of nuclear facilities and material by working closely with national authorities and continuously enhancing IPPAS.

"We need to make stakeholders and policymakers aware of the national security measures needed to keep radioactive material safe and secure. The IPPAS mission has been a good platform and opportunity for us to gain peer reviews and input so we can upgrade our security measures," said Delwende Nabayaogo, Nuclear Security Officer at the National Radiation Protection and Nuclear Safety Authority in Burkina Faso.

OSART observes strong commitment and improvements

Countries can seek independent, international perspective and advice by requesting OSART missions to identify opportunities to further improve the operational safety performance of their nuclear power plants.

"Continuous improvement, openness and transparency were the reasons why we invited this mission. I am very pleased that Agency experts noted significant positive progress compared to the pre-OSART mission in 2019," said Branislav Strycek, General Director of Slovenské elektrárne, the operator of Mochovce nuclear power plant in Slovakia, where an OSART follow-up mission took place in September 2021.

OSART missions provide operators with insights on how to improve safety further and have led to enhanced safety performance worldwide — with over 95% of OSART recommendations and suggestions resolved or addressed satisfactorily by operators during the OSART follow-up mission. Over the past 39 years, 368 OSART missions, including 155 follow-up missions, have been conducted in 37 Member States.

Radiation and Transport Safety

Objective

To support Member States in improving radiation safety of people and the environment through the development of safety standards and by providing for their application. To support Member States in establishing the appropriate safety infrastructure through support and implementation of the Code of Conduct on the Safety and Security of Radioactive Sources and Supplementary Guidance, as well as through safety reviews and advisory services. To support Member States in capacity building, through education and training, and in encouraging the exchange of information and experience.

Radiation Safety and Monitoring

The Postgraduate Educational Course (PGEC) in Radiation Protection and the Safety of Radiation Sources continued to be an effective programme though which Member States address their needs for training personnel with regulatory or advisory functions in radiation safety. The Agency held five PGECs on Radiation Protection and the Safety of Radiation Sources, in Algeria, Argentina, Belarus, Ghana and Jordan in different languages.

The Agency held a virtual Technical Meeting on Developing Effective Methods for Radiation Protection Education and Training of Health Professionals in March 2021 to share experiences in developing education and training and to identify potential gaps and/or issues.

The Agency held a virtual Technical Meeting on the Establishment of a Web-based Information Exchange Platform for Occupational Radiation Protection in Industries involving Naturally Occurring Radioactive Material in November 2021.

The Agency published an educational handbook on safety culture in medical uses of radiation, entitled Radiation Safety Culture Trait Talks, in March 2021, which is structured around ten principles, or traits, that contribute to a strong safety culture.

The Agency published an electronic handbook on radiation safety culture in health care settings in February 2021.

Regulatory Infrastructure

The Agency surveyed 124 regulatory bodies for radiation safety to identify the impacts of the COVID-19 pandemic on the safety of facilities using radiation sources and their regulatory oversight. Early analysis suggests that many regulatory functions have been diminished and some companies may have to close as a result of the economic impact of the pandemic, and there could be an increased risk of radioactive sources becoming orphaned. This information, and other information relevant to the COVID-19 pandemic,

was provided to the 65th regular session of the General Conference within document GC(65)/INF/9.

The Agency published *Application of a Graded Approach in Regulating the Safety of Radiation Sources* (IAEA-TECDOC-1974) in July 2021 and *Application of a Graded Approach in Regulating Nuclear Installations* (IAEA-TECDOC-1980) in November 2021.

The Agency launched on-line tools for the control of radioactive material inadvertently incorporated into scrap metal in May 2021 to facilitate the exchange of information between Member States and encourage the participation of scrap metal industries. Furthermore, in June 2021, the Agency launched an e-learning training course entitled 'Control of Radioactive Material Inadvertently Incorporated into Scrap Metal'.

Transport Safety

The Agency launched Version 2.0 of Modules 0–4 of the transport safety e-learning platform to reflect *Regulations for the Safe Transport of Radioactive Material* (IAEA Safety Standards Series No. SSR-6 (Rev. 1)), in Spanish in June 2021. In addition, the Agency launched Version 2.0 of Modules 0–4 of the transport safety e-learning platform to reflect IAEA Safety Standards Series No. SSR-6 (Rev. 1), in Chinese in October 2021.

The Agency held a virtual Technical Meeting on Denials of Shipment — Issues and Solutions in March 2021 to provide a forum to discuss the options for addressing denials of, and delays in, the shipment of radioactive material.

Systems and Services for Dosimetry Laboratories

The Agency launched a Dose Management System for dose information management in dosimetry services laboratories in Member States in March 2021.

Radioactive Waste Management and Environmental Safety

Objective

To support Member States in improving the safety of radioactive waste and spent fuel management, including geologic repositories for high level waste, decommissioning, remediation and environmental releases, through the development of safety standards and providing for their application. To support Member States in improving the safety of radioactive waste and spent fuel management, including geologic repositories for high level waste, decommissioning, remediation and environmental releases through peer reviews and advisory services, and to assist their adherence to, and facilitating implementation of, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. To support Member States in capacity building through education and training, and encouraging the exchange of information and experience.

Radioactive Waste and Spent Fuel Management

The Agency continued developing guidance on conducting Integrated Regulatory Review Service (IRRS) and Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) missions in a back-to-back manner. This guidance supports Member States to plan in a coordinated manner and to implement IRRS and ARTEMIS missions sequentially, noting that the utilization of flexibility and adaptability in the services will not compromise their respective integrity and effectiveness. This guidance has been developed by an Agency task force and was shared with the European Nuclear Safety Regulators Group in November 2021. To date, six countries have invited such missions. The feedback collected from these missions will be used to improve and finalize the guidance.

The Agency held a series of virtual national workshops on IRRS missions and self-assessments based on the Self-Assessment of Regulatory Infrastructure for Safety (SARIS) methodology and the new on-line version of SARIS (eSARIS).

Assessment and Management of Environmental Releases

The Agency held a virtual Technical Meeting of the International Working Forum on Regulatory Supervision of Legacy Sites on the Identification and Prioritization of Sites for Remediation in November 2021. As a result, in December 2021, the Agency organized a virtual Joint Regional Workshop of the International Working Forum on Regulatory Supervision of Legacy Sites and the Coordination Group for Uranium Legacy Sites on Licensing for Remediation Projects, to support Central Asian Member States in the development of effective and efficient regulatory supervision of legacy sites.

Visit by the Agency review team to the Fukushima Daiichi nuclear power plant in November 2021. (Photograph courtesy of Tokyo Electric Power Company.)

There has been increased international attention regarding the handling of Advanced Liquid Processing System (ALPS) treated water at the Fukushima Daiichi nuclear power plant. In response to a request from Japan, the Agency has formed a task force to conduct a review that will assess the Government of Japan's plan to discharge ALPS treated water against Agency safety standards. The review started in September 2021.

Decommissioning and Remediation Safety

The Agency held two virtual Technical Meetings of the International Project on Completion of Decommissioning, in June and October 2021, to continue the collaboration and information exchange between Member States on the definition of end states and the completion of decommissioning. The Agency also held two virtual Technical Meetings of the International Project on Decommissioning of Small Facilities, in May and November 2021, to provide a platform for collaborative work and the exchange of experiences and lessons learned related to the decommissioning of small medical, industrial and research facilities.

The Agency held a virtual Technical Meeting on Decommissioning Planning for Uranium Production Facilities in December 2021. The Agency also held the Third Technical Meeting of the International Project on Decommissioning of Small Facilities virtually in May 2021.

Joint Convention

The Agency held a virtual workshop in March 2021 to provide technical assistance to Pakistan in adhering to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

Nuclear Security

Objective

To contribute to global efforts to achieve effective nuclear security, by establishing comprehensive nuclear security guidance and promoting its use through peer reviews and advisory services and capacity building, including education and training. To assist in adherence to, and implementation of, relevant international legal instruments, and in strengthening the international cooperation and coordination of assistance in a manner that underpins the use of nuclear energy and applications. To play the central role and enhance international cooperation in nuclear security, in response to General Conference resolutions and Board of Governors directions.

The Convention on the Physical Protection of Nuclear Material (CPPNM) and Its Amendment

The Secretariat intensified its efforts in 2021 to assist Parties in preparing for the Conference of the Parties to the Amendment to the Convention on the Physical Protection of Nuclear Material, which is planned to be held from 28 March to 1 April 2022. In February 2021, the Agency held a virtual meeting of the Preparatory Committee for the Conference, which undertook relevant preparations, including the development of draft Rules of Procedure and a draft annotated agenda, for the 2022 Conference. Over 240 participants representing more than 90 Parties to the CPPNM and its Amendment, as well as Parties to the CPPNM only, participated in the meeting. The Agency also held a series of virtual regional meetings in November and December 2021; and two rounds of open-ended consultations in October and December 2021 to assist Parties to prepare for the 2022 Conference, which were attended by 183 participants from 63 States and the European Atomic Energy Community.

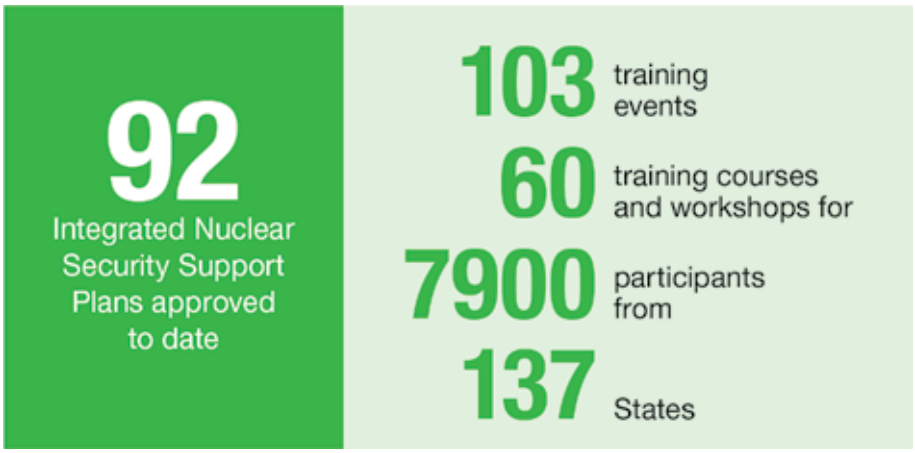
The Agency continued encouraging universal adherence to, and effective implementation of, the CPPNM and its Amendment, and provided technical and legislative assistance, upon request. The Agency sent letters in March 2021 to States not party to the CPPNM, as well as to those that are party to the CPPNM but not to its Amendment, urging them to join the CPPNM and/or its Amendment. To mark the fifth anniversary of the entry into force of the Amendment on 8 May 2021, the Director General addressed States via a video message. The Agency conducted a series of four webinars to promote the universalization of the CPPNM and its Amendment in August 2021, which were attended by about 200 participants from 62 States. In addition, the Agency conducted a virtual international seminar and regional workshops for Russian speaking countries, Western Asia and the Middle East in May 2021, and for Africa in December 2021. A further four States became party to the CPPNM or its Amendment in 2021.

Nuclear Security Guidance

Three new IAEA Nuclear Security Series guidance publications and three revisions of existing publications were issued. The new publications address nuclear security culture, computer security for nuclear security, and the design of physical protection systems for nuclear material and nuclear facilities. At the end of 2021, the IAEA Nuclear Security Series comprised 42 publications.

Needs Assessment and Capacity Building

Two Member States approved Integrated Nuclear Security Support Plans, bringing the total number of approved plans to 92. The Agency conducted 103 training events, including 60 training courses and workshops, for 7900 participants from 137 States. This included the first two Schools on Nuclear Security for the Marie Skłodowska-Curie Fellowship Programme, with over 50 participants overall.



The Agency continued to provide related e-learning opportunities, with over 1500 users from 125 States completing over 2600 e-learning modules in 2021.

Risk Reduction

The Agency continued to support Member States in protecting nuclear and other radioactive material during and after use. The Agency assisted in the removal of 3 high activity disused radioactive sources from 2 Member States, continued to support the ongoing removal of 31 high activity disused radioactive sources in 2 Member States and preparatory work for the removal of an additional 18 sources from 4 Member States, and

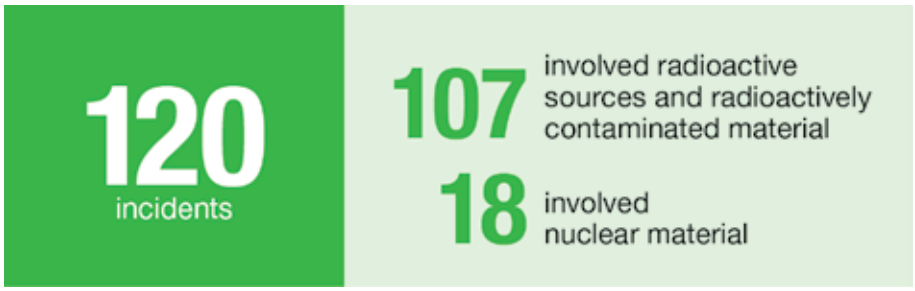
assisted in the consolidation of 9 high activity disused radioactive sources in 1 Member State. In addition, the Agency completed physical protection upgrades in four Member States at three research reactors and one nuclear power plant. It also provided assistance in drafting nuclear security regulations to eight Member States.

Major Public Events

In 2021, the Agency provided assistance to 7 Member States to strengthen nuclear security measures on the preparation and support for 7 major public events, including loaning a total of 760 radiation detection instruments.

Incident and Trafficking Database

In 2021, States reported 120 incidents to the Incident and Trafficking Database: 107 involved radioactive sources and radioactively contaminated material and 18 involved nuclear material, with 5 incidents involving more than 1 of the aforementioned types of material. A total of 7 reported incidents involved acts of trafficking or malicious use, while there were 24 reported incidents in which the intent to conduct trafficking of malicious use could not be determined.



Nuclear Security Fund

In the period 1 January to 31 December 2021, the Agency accepted pledges and received contributions to the Nuclear Security Fund in the amount of €30 383 344 from the following Member States: China, the Czech Republic, Denmark, Finland, France, Japan, the Republic of Korea, New Zealand, Norway, the Russian Federation, Spain, Switzerland, the United Kingdom and the United States of America, among other contributors.

CASE STUDY

Strengthening Transport Security in the Republic of Moldova

In 2021, the Agency donated a specialized cargo vehicle to the Republic of Moldova in order to facilitate the safe and secure transport of radioactive sources to designated specialized storage locations, in turn supporting the country's efforts towards strengthening its national nuclear security infrastructure.

"In recent years, the security of radioactive material has been highlighted as a key priority for the Republic of Moldova, particularly related to locating and securing orphan sources — sources that are lost, missing or were just never registered — and transporting them to secure storage facilities," said Iulian Gisca, Director of the Moldovan National Radioactive Waste Management Company. "Part of this is ensuring that when these sources are located, they can be safely and securely transported to designated storage facilities. For this reason, this specialized cargo vehicle is vital."

There are several radioactive sources in the Republic of Moldova, as well as small quantities of nuclear material which are used in medical and industrial applications and for research purposes. The application of nuclear science and technology in the Republic of Moldova has been supported by the Agency through its Technical Cooperation Programme. The programme supports relevant authorities to ensure the safety and security of nuclear and other radioactive material during their use and storage.

Worldwide, an estimated 20 million shipments of radioactive material take place every year. The Agency assists governments and stakeholders in enhancing their capabilities, to ensure both the safety and the security of nuclear and other radioactive material during transport — as well as during its use and storage.

This vehicle, donated by the Agency, has advanced features which support the Republic of Moldova in enhancing its transport security capabilities.

In order to assess the Republic of Moldova's capabilities for the security of radioactive material during its use, storage and transport, Agency experts visited the country in 2018. Subsequently, they recommended the purchase of a specialized truck to enable the safe and secure transport of radioactive sources.

The requirements for the vehicle were drawn up by the Moldovan National Radioactive Waste Management Company, the National Agency for the Regulation of Nuclear and Radiological Activities (ANRANR) and international experts, with help from the Agency. "The vehicle's state of the art security system includes sophisticated detection measures, delay barriers, and tracking and communication capabilities, which will significantly support Moldova's transport security capabilities," said David Ladsous, Head of the Agency's Transport Security Unit. "This vehicle donation is just one way in which the Agency assists countries in the development of their national physical protection regimes for the transport of nuclear and other radioactive material," explained Elena Buglova, Director of the Agency's Division of Nuclear Security. "This support helps the international community to protect people, property and the environment from malicious acts that could occur during transport."

The Agency is also helping the Republic of Moldova to draft transport security regulations and to conduct training courses for national nuclear authority personnel. Following a successful workshop on transport security exercises, held in Romania at the start of 2021, a regional workshop on the topic was also conducted, in order to support coordination between the Republic of Moldova and Romania for safe and secure cross-border shipments of radioactive sources.

Nuclear Verification

Nuclear Verification

186

States with safeguards agreements in force of which

138 **States had additional protocols in force**

over

3 000

verification activities undertaken

1 334

nuclear facilities and locations outside facilities under safeguards

226 116

significant quantities of nuclear material under safeguards

over

14 600

days of in-field verification and

more than

2 100

days spent in quarantine

Conclusions*

72 States
all nuclear material remained in peaceful activities

105 States
declared nuclear material remained in peaceful activities

3 States
nuclear material, facilities or other items to which safeguards had been applied remained in peaceful activities

5 States
nuclear material in selected facilities to which safeguards had been applied remained in peaceful activities

* These States do not include the Democratic People's Republic of Korea (DPRK), where the Agency did not implement safeguards and, therefore, could not draw any conclusion.

Nuclear Verification [1,2]

Objective

To deter the proliferation of nuclear weapons by detecting early the misuse of nuclear material or technology and by providing credible assurances that States are honouring their safeguards obligations, and, in accordance with the Agency's Statute, assist with other verification tasks, including in connection with nuclear disarmament or arms control agreements, as requested by States and approved by the Board of Governors.

Implementation of Safeguards in 2021

Implementing safeguards and other verification activities in 2021 remained challenging as a result of the global COVID-19 pandemic. For example, Agency inspectors and technicians on missions spent a total of more than 2100 days in quarantine outside Austria. Nevertheless, with considerable sustained effort and continued adaptation to the circumstances, the Agency carried out over 3000 verification activities (2850 in 2020) and spent more than 14 600 days in the field conducting those activities (12 700 in 2020). This ensured that the Agency was able to draw soundly based conclusions for all States in which safeguards were implemented by the Agency for 2021.

At the end of every year, the Agency draws a safeguards conclusion for each State for which safeguards are applied. This conclusion is based on an evaluation of all safeguards relevant information available to the Agency in exercising its rights and fulfilling its safeguards obligations for that year.

In 2021, safeguards were applied for 185 States[3,4] with safeguards agreements in force with the Agency. Of the 132 States that had both a comprehensive safeguards agreement (CSA) and an additional protocol (AP) in force (see Fig. 1), the Agency drew the broader conclusion that *all* nuclear material remained in peaceful activities for 72 States[5]; for the remaining 60 States, as the necessary evaluation regarding the absence of undeclared nuclear material and activities for each of these States remained ongoing, the Agency concluded

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1 The designations employed and the presentation of material in this section, including the numbers cited, do not imply the expression of any opinion whatsoever on the part of the Agency or its Member States concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

2 The referenced number of State Parties to the Treaty on the Non-Proliferation of Nuclear Weapons is based on the number of instruments of ratification, accession or succession that have been deposited.

3 These States do not include the Democratic People's Republic of Korea (DPRK), where the Agency did not implement safeguards and, therefore, could not draw any conclusion.

4 And Taiwan, China.

5 And Taiwan, China.

FIG. 1. Agency inspectors wearing personal protective equipment during training.

only that *declared* nuclear material remained in peaceful activities. For 45 States with a CSA but with no AP in force, the Agency concluded only that *declared* nuclear material remained in peaceful activities.

For those States for which the broader conclusion has been drawn, the Agency is able to implement integrated safeguards: an optimized combination of measures available under CSAs and APs to maximize effectiveness and efficiency in fulfilling the Agency's safeguards obligations. Integrated safeguards were implemented for the whole of 2021 for 69 States[6,7].

Safeguards were also implemented with regard to nuclear material in selected facilities in the five nuclear-weapon States party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) under their respective voluntary offer agreements. For these five States, the Agency concluded that nuclear material in selected facilities to which safeguards had been applied remained in peaceful activities or had been withdrawn from safeguards as provided for in the agreements.

For three States not party to the NPT, the Agency implemented safeguards pursuant to item-specific safeguards agreements based on INFCIRC/66/Rev.2. For these States, the

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6 Albania, Andorra, Armenia, Australia, Austria, Bangladesh, Belgium, Botswana, Bulgaria, Burkina Faso, Canada, Chile, Croatia, Cuba, the Czech Republic, Denmark, Ecuador, Estonia, Finland, Germany, Ghana, Greece, Holy See, Hungary, Iceland, Indonesia, Ireland, Italy, Jamaica, Japan, Jordan, Kazakhstan, the Republic of Korea, Kuwait, Latvia, Libya, Liechtenstein, Lithuania, Luxembourg, Madagascar, Mali, Malta, Mauritius, Monaco, Montenegro, the Netherlands, New Zealand, North Macedonia, Norway, Palau, Peru, the Philippines, Poland, Portugal, Romania, Seychelles, Singapore, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Tajikistan, the United Republic of Tanzania, Türkiye, Uruguay, Uzbekistan and Viet Nam.

7 And Taiwan, China.

Agency concluded that nuclear material, facilities or other items to which safeguards had been applied remained in peaceful activities.

As of 31 December 2021, eight States Parties to the NPT had yet to bring CSAs into force pursuant to Article III of the Treaty. For these States Parties, the Agency could not draw any safeguards conclusions.

Conclusion of safeguards agreements and APs, and amendment and rescission of small quantities protocols

The status of safeguards agreements and APs as of 31 December 2021 is shown in Table A6 in the Annex to this report. During 2021, a CSA with a small quantities protocol (SQP) and an AP entered into force for Eritrea. A CSA with an SQP entered into force for the Federated States of Micronesia. An AP was signed and entered into force for Zimbabwe. Another AP was approved by the Board of Governors for Sierra Leone. SQPs were amended for Belize, Brunei Darussalam, Maldives, Saint Lucia and Sudan. SQPs were rescinded for Malta and the United Arab Emirates.

The Agency continued to facilitate the conclusion of safeguards agreements and APs (Fig. 2), and the amendment or rescission of SQPs. In 2021, the Director General sent letters to non-nuclear-weapon States party to the NPT that had not yet concluded or brought into force CSAs in connection with the NPT, calling upon them to do so. The Director General also sent letters to States with CSAs but without APs, encouraging them to conclude and bring into force APs to their CSAs. In these letters, he also reminded relevant States with original SQPs of his earlier calls for amendment or rescission of the SQPs. At the end of 2021, 96 States with CSAs in force had operative SQPs, of which 70 SQPs were based on the revised standard text. Ten States had rescinded their SQPs (Fig. 3). The Agency continued to implement the *Plan of Action to Promote the Conclusion of Safeguards Agreements and Additional Protocols*, which was updated in September 2021. In April 2021, the Secretariat held a Technical Meeting focused on the Agency's efforts to strengthen safeguards implementation in States with SQPs.

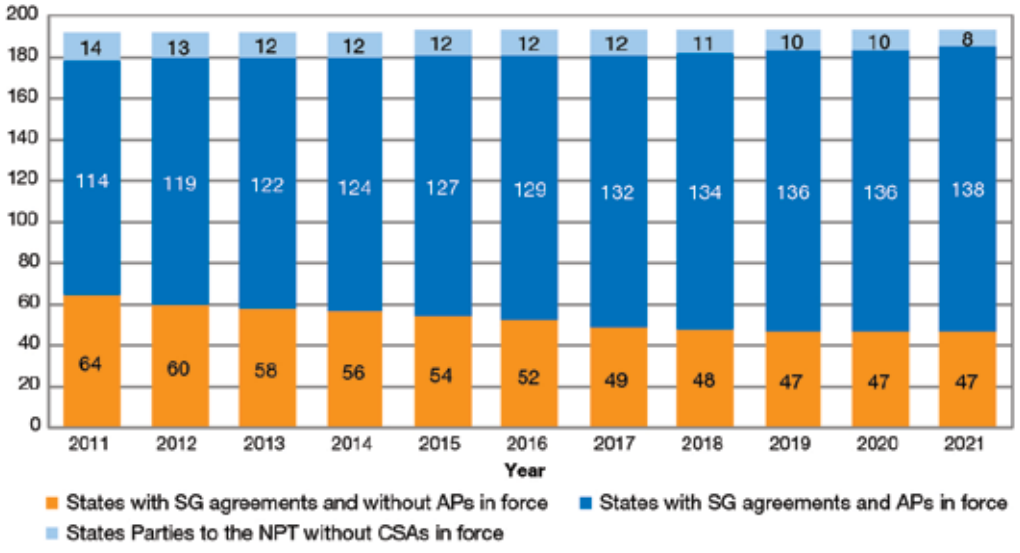


FIG. 2. Number of APs for States with safeguards agreements in force, 2011–2021 (the Democratic People's Republic of Korea is not included).

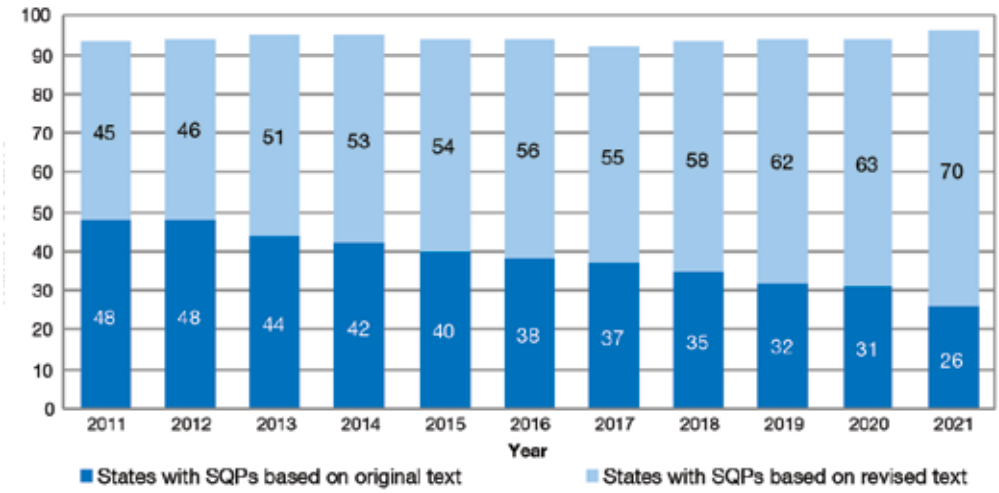


FIG. 3. Number of States with SQPs, 2011–2021.

Islamic Republic of Iran (Iran)

Until 23 February 2021, the Agency, in light of United Nations Security Council resolution 2231 (2015), continued to verify and monitor the nuclear-related commitments of the Islamic Republic of Iran (Iran) under the Joint Comprehensive Plan of Action (JCPOA). From 23 February 2021 onwards, however, the Agency's verification and monitoring activities in relation to the JCPOA were seriously affected following Iran's decision to stop the implementation of those commitments, including the AP. During the year, the Director General submitted to the Board of Governors and in parallel to the United Nations Security Council 4 quarterly reports, and 30 reports providing updates on developments in between the issuance of the quarterly reports, entitled *Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231* (2015).

During 2021, the Agency continued its efforts to engage Iran in order to clarify and resolve the issues related to the presence of nuclear material particles of anthropogenic origin at three undeclared locations in Iran, and the issues related to a fourth undeclared location in Iran. The lack of progress in clarifying the Agency's questions concerning the correctness and completeness of Iran's safeguards declarations seriously affected the Agency's ability to provide assurance of the exclusively peaceful nature of Iran's nuclear programme. The Director General submitted four reports to the Board of Governors entitled *NPT Safeguards Agreement with the Islamic Republic of Iran*.

Syrian Arab Republic (Syria)

In August 2021, the Director General submitted a report to the Board of Governors entitled *Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic*. The Director General informed the Board of Governors that no new information had come to the knowledge of the Agency that would have an impact on the Agency's assessment that it was very likely that a building destroyed at the Dair Alzour site was a nuclear reactor that should have been declared to the Agency by Syria[8]. In 2021, the Director General continued to urge Syria to cooperate fully with the Agency in connection with all unresolved issues.

[8] The Board of Governors, in its resolution GOV/2011/41 of June 2011 (adopted by a vote), had, inter alia, called on Syria to urgently remedy its non-compliance with its NPT Safeguards Agreement and, in particular, to provide the Agency with updated reporting under its Safeguards Agreement and access to all information, sites, material and persons necessary for the Agency to verify such reporting and resolve all outstanding questions so that the Agency could provide the necessary assurance as to the exclusively peaceful nature of Syria's nuclear programme.

Democratic People's Republic of Korea (DPRK)

In August 2021, the Director General submitted a report to the Board of Governors and the General Conference entitled *Application of Safeguards in the Democratic People's Republic of Korea*. In 2021, no verification activities were implemented in the field, but the Agency continued to monitor developments in the DPRK's nuclear programme and to evaluate all safeguards relevant information available to it. Some of the DPRK's nuclear facilities appeared not to be operating, while activities at some other facilities appeared to continue or were developed further. The Agency has not had access to the Yongbyon site or to other locations in the DPRK. Without such access, the Agency cannot confirm the operational status or configuration/design features of the facilities or locations, or the nature and purpose of the activities conducted therein. The continuation of the DPRK's nuclear programme is a clear violation of relevant United Nations Security Council resolutions and is deeply regrettable.

Enhancing Safeguards

State-level safeguards implementation

The Agency continued to enhance the consistency and effectiveness of safeguards implementation at the State level through a project aimed at improving the development and implementation of State-level safeguards approaches (SLAs) using a structured approach. In September, the Secretariat held a Technical Meeting on improving consistency in the implementation of SLAs. During 2021, based on updated internal procedures and guidance, the Agency continued to update SLAs for States with the broader conclusion.

Cooperation with State and regional authorities

In 2021, the Agency conducted, virtually and in person, 16 international, regional and national training courses, including courses with counterparts in Japan, the Republic of Korea, the Russian Federation and the United States of America. In total, more than 200 experts from some 50 States were trained on safeguards related topics, including two courses specifically for States with SQPs. The Agency hosted six webinars, each with a focus on addressing the specific needs of the States involved. These courses provided participants with the knowledge and skills to help strengthen their State system of accounting for and control of nuclear material (SSAC) and the implementation of safeguards.

The Agency continued to make use of its learning management system — the Cyber Learning Platform for Network Education and Training — to develop and host courses for anyone with a NUCLEUS account, thereby increasing global access to learning opportunities regarding safeguards related topics. The platform also provides resources for participants enrolled in SSAC training courses. By the end of the year, there were over 1000 enrolled users.

To further help States strengthen the effectiveness of their State or regional authority responsible for safeguards implementation (SRA) and of their respective SSAC, the Agency continued the implementation of the IAEA Comprehensive Capacity-Building Initiative for SSACs and SRAs (COMPASS) to provide assistance and services tailored to the needs of each of the seven participatory States (see case study). The Agency published *IAEA Safeguards and SSAC Advisory Service (ISSAS) Guidelines* (IAEA Services Series No. 13 (Rev. 1)), which includes a guide for States on conducting self-assessments.

FIG. 4. The XCVD in use during training.

Safeguards equipment and tools

Despite the travel restrictions owing to the COVID-19 pandemic, the Agency ensured that instrumentation and monitoring equipment used by inspectors during in-field verification activities or installed in nuclear facilities continued to operate. By the end of the year, 1640 unattended safeguards data streams were being collected remotely from 148 facilities in 32 States[9] around the world. The Agency also had 1378 cameras operating or ready to use at 254 facilities in 35 States[10], and the transition to the latest generation of surveillance systems (based on DCM-C5/-A1 camera modules) was 85% complete. In 2021, six additional unattended monitoring systems were installed in two States, which meant that by the end of the year, 182 such systems were installed in 24 States.

The Agency's passive gamma emission tomography system was routinely used by inspectors to verify damaged fuel assemblies transitioning to dry storage.

The Agency successfully qualified a new passive seal that will now be introduced as a replacement for the traditional E-CAP metal seal. In parallel, the development of a new active seal progressed according to plan.

Agency experts were able to generalize the authorization of the next generation Cherenkov viewing device (XCVD) for verification activities in all Member States (Fig. 4). The palmtop Raman Analyser was authorized, supporting over 125 nuclear material signatures to enhance field verification efficiency by offering immediate nuclear material identification.

9 And Taiwan, China.

10 And Taiwan, China.

Safeguards analytical services and methodologies

The Agency's Network of Analytical Laboratories consists of the Agency's Safeguards Analytical Laboratories and 24 other qualified laboratories in various Member States. During the year, six additional laboratories for sample analysis and reference material provision were in the process of qualification.

In 2021, the Agency collected 705 nuclear material samples for nuclear material accountancy, and 144 nuclear material samples for material characterization. The large majority of these were analysed by the Agency's Nuclear Material Laboratory. In addition, seven heavy water samples were collected for analysis by the Network of Analytical Laboratories. The Agency also collected 473 environmental samples, resulting in analysis of 1074 subsamples.

The new Statistical Evaluation Platform for Safeguards was fully deployed and further enhanced, providing the Agency with a state of the art analytical environment supporting, inter alia, material balance evaluation with upgraded statistical methodologies and streamlined processes. The 'Environmental Sampling Environment Enhancement' project to modernize and integrate the environmental sampling database and modelling/evaluation tools was initiated in 2021. Despite the challenging circumstances brought about by the COVID-19 pandemic, the international target values revision project 'ITV-2020' was successfully carried out based on the deployment of a collaborative virtual platform.

In the area of open sources, including satellite imagery, the Agency continued to diversify its sources of safeguards relevant information, benefiting, for instance, from new subscriptions related to science and technology publications and new remote sensors. With a view to addressing the constantly growing amount of information available to it and better extract safeguards relevant information, the Agency initiated a number of actions in the field of artificial intelligence to enhance analytical effectiveness and efficiency related to the use of text and image sources.

Developing the Safeguards Workforce

In 2021, the Agency conducted 49 distinct safeguards training courses (as some were held more than once, a total of 89 training courses were provided overall, of which 18 were held outside Vienna) helping to provide safeguards inspectors, analysts and support staff with the necessary core and functional competencies. Seven courses on industrial safety were held in 2021. The Introductory Course for Agency Inspectors, which comprises ten modules and lasts for six months, was held for nine new inspectors.

The 2021 Safeguards Traineeship Programme for young graduates and junior professionals commenced in February 2021, involving nine participants from Angola, Indonesia, Jordan, Malaysia, Saudi Arabia, Senegal, Sri Lanka, Tunisia and the United Arab Emirates.

FIG. 5. The signing to establish the Swiss Member State Support Programme.

Preparing for the Future

In 2021, Member State Support Programmes (MSSPs) remained essential to enabling the evaluation, design, testing and preparation of new safeguards technologies to address new verification challenges. A new MSSP was established for the first time since 2013 — the Swiss Support Programme (Fig. 5). To further broaden the support base for Agency safeguards, the Agency also forged new partnerships by signing Practical Arrangements with five 'non-traditional' entities.

CASE STUDY

Agency Assists Countries to Meet Their Safeguards Obligations Effectively and Efficiently

Nuclear material accountancy and control is a safeguards measure of fundamental importance for the Agency's safeguards mission. The IAEA Comprehensive Capacity-Building Initiative for SSACs and SRAs (COMPASS) is aimed at strengthening the effectiveness of State systems of accounting for and control of nuclear material (SSACs) while enhancing cooperation between the State or regional authority responsible for safeguards implementation (SRA) and the Agency. Building on 40 years of support for the implementation of safeguards, COMPASS uses a tailored approach for each country participating in this initiative.

States establish and maintain SSACs as part of their safeguards obligations. Activities performed by an SSAC include the establishment of a measurement system to determine the quantities of nuclear material received, produced, shipped or removed from inventories, and then reporting this to the Agency. Such reporting, in turn, provides the basis for the Agency's independent verification of such nuclear material.

By identifying specific areas where States can benefit from further safeguards related assistance, COMPASS allows the Agency and national counterparts to agree on a customized work plan that addresses individual needs and supports States in strengthening the capacity of their SSACs and SRAs. This ranges from the provision of safeguards-related legislative and regulatory assistance, safeguards training, equipment and information technology (IT) support, to expert assistance. In 2021, the Agency began to roll out COMPASS activities to all seven COMPASS States trialling the initiative: Guatemala, Jordan, Malaysia, Rwanda, Saudi Arabia, Türkiye and Uzbekistan.

Participants from a COMPASS pilot State are shown how safeguards measures are applied at a nuclear facility.

CASE STUDY

Over the course of the year, several in-person and on-line safeguards training courses and workshops were held. In one event held in Vienna, participants were given the opportunity to visit a nuclear facility to see how safeguards measures are applied in practice. Legislative and regulatory support was also provided during the year to help the participating States strengthen their safeguards-related legislation and regulatory frameworks. In addition, hand-held radionuclide identification devices were delivered to enhance technical capacity in implementing safeguards. IT equipment with appropriate software and support was also supplied for a number of States to facilitate the secure collection, processing and transmission of nuclear material accountancy data.

In 2021, all seven COMPASS States agreed to their respective two-year work plans. To enable the effective implementation of these plans, 13 Member State Support Programmes and other supporting States are providing financial and/or in-kind contributions to COMPASS.

"COMPASS is already delivering on its key areas of assistance to the pilot States," said Massimo Aparo, Deputy Director General and Head of the Department of Safeguards. "I look forward to continuing the roll-out of work plans with pilot States over the course of 2022 and seeing the associated benefits in safeguards implementation."

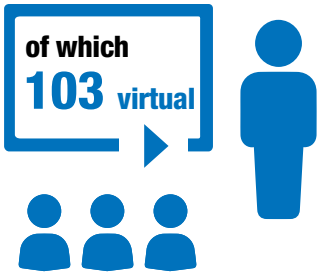
Technical Cooperation

Management of Technical Cooperation for Development

146
countries and territories receiving support through the Agency's technical cooperation programme

including **34** least developed countries

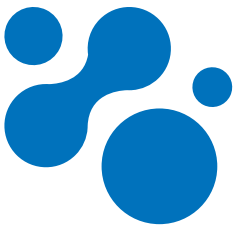
119
regional and interregional training courses



Technical Cooperation Fund

€89.6 million
target for voluntary contributions

€85.3 million received
95.2% rate of attainment



4 imPACT
review missions

743
fellows and scientific visitors, of which
11 virtual

2898
training course participants, of which
2526 virtual

2021

973
active projects

603
projects closed or in closure at the end of 2021

116 Country Programme Frameworks valid

2320
purchase orders issued

value of purchase orders issued
€64.2 million

Management of Technical Cooperation for Development

Objective

To develop and implement a need-based, responsive technical cooperation programme in an effective and efficient manner, and thus to strengthen technical capacities of Member States in the peaceful application and safe use of nuclear technologies for sustainable development.

The Technical Cooperation Programme

Programme delivery

The technical cooperation programme is the Agency's major vehicle for transferring nuclear technology and building capacity in nuclear applications in Member States. It supports national efforts to achieve development priorities, including the targets underpinning the Sustainable Development Goals (SDGs), and encourages cooperation between Member States and with partners.

The main areas of Agency technical cooperation in 2021 were health and nutrition, food and agriculture, and nuclear knowledge development and management (Fig. 1).

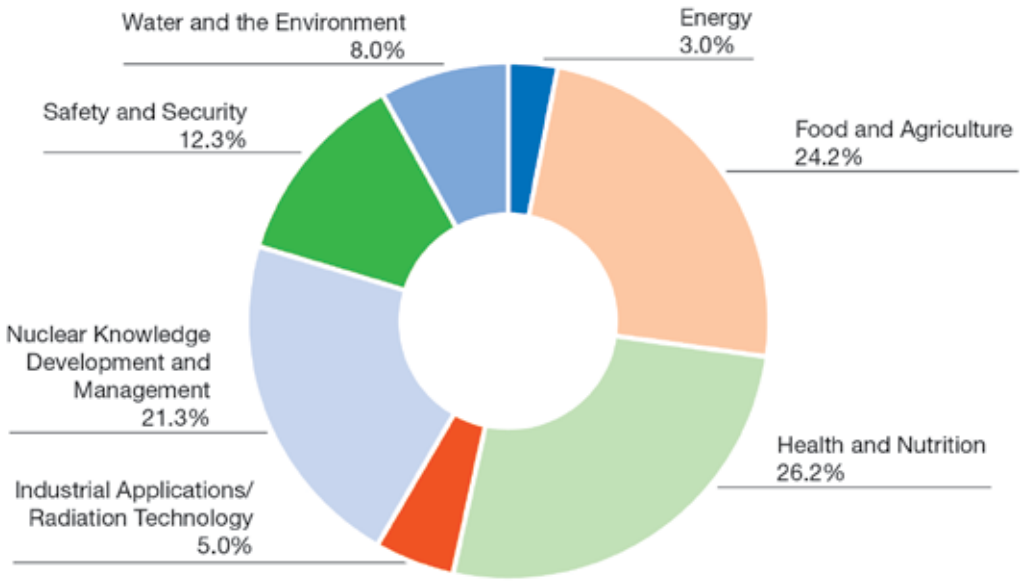


FIG. 1. Technical cooperation programme disbursements (actuals) by technical field for 2021. (Percentages do not add up to 100% owing to rounding.)

Financial highlights

Payments to the 2021 Technical Cooperation Fund totalled €86.4 million (including assessed programme cost arrears, National Participation Costs and miscellaneous income), against the target of €89.6 million. The rate of attainment on payments at the end of 2021 reached 95.2% (Fig. 2). The Technical Cooperation Fund implementation rate was 84.1%.

FIG.2. Trends in the rate of attainment, 2012–2021.

Country Programme Frameworks and Revised Supplementary Agreements

The number of valid Country Programme Frameworks (CPFs) reached 116 by the end of 2021.

The total number of Revised Supplementary Agreements Concerning the Provision of Technical Assistance by the International Atomic Energy Agency was 142.

18 CPFs were signed in 2021

Burundi	Madagascar	Palau	Slovakia
Czech Republic	Malawi	Portugal	United Arab Emirates
Djibouti	Mali	Saint Vincent and the Grenadines	Uzbekistan
Egypt	Marshall Islands	Singapore	Zambia
Ghana	Niger		

Regional Cooperative Agreements and Regional Programming

Africa

Technical cooperation projects under the African Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (AFRA) continued to support the training of a new generation of African scientists who are applying nuclear science and technology for Africa's development.

AFRA State Parties finalized the design of 19 regional technical cooperation projects for the 2022–2023 programme cycle. These will contribute to the implementation of the AFRA Regional Strategic Cooperative Framework for 2019–2023.

Participants at the 32nd AFRA Technical Working Group Meeting (TWGM) in July discussed the performance of the AFRA programme and made recommendations to improve

delivery and effectiveness. AFRA State Parties were invited to develop a human resource development plan for nuclear science and technology, linked to national development plans and CPFs.

Participants at the 32nd Meeting of AFRA Representatives in September endorsed the recommendations of the 32nd AFRA TWGM, and encouraged AFRA State Parties to identify more training centres in the region that could be used to meet the growing training needs of the region. Participants also approved the AFRA Annual Report for 2020, and the composition of the new AFRA management committees, 60% of which is female.

Asia and the Pacific

The 2024–2029 Regional Programme Framework for the Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (RCA) for the Asia and the Pacific region was approved at the 43rd Meeting of National RCA Representatives in April. Socioeconomic impact assessments of the RCA radiotherapy and non-destructive testing programmes, covering a 20-year period, have been prepared.

The Board of Representatives of the Co-operative Agreement for Arab States in Asia for Research, Development and Training related to Nuclear Science and Technology (ARASIA) adopted a mechanism for the selection of new Chairpersons, which will be incorporated in the ARASIA Guidelines and Operating Rules. A mechanism for the designation of ARASIA regional resource centres through the signature of Memoranda of Understanding has also been agreed, with the intention of promoting regional collaboration for capacity building, human resource development and the exchange of best practices. The ARASIA-designated regional resource centres for secondary standards dosimetry and for nuclear medicine have been supporting the implementation of ARASIA technical cooperation projects, optimizing the use of regional capabilities and enhancing capacity building and cooperation among ARASIA State Parties.

As a result of the Practical Arrangements signed with the Association of Southeast Asian Nations in 2019, regional projects on emergency preparedness and response, agricultural value chain improvement and the protection of cultural heritage objects were developed for the 2022–2023 technical cooperation cycle.

Agency experts and medical staff discuss radiotherapy during a visit to Tashkent City Oncology Centre, Uzbekistan.

Europe

Technical cooperation activities in Europe were carried out in close collaboration with Member States, and in alignment with the Europe Regional Strategy, the Europe Regional Profile and the priorities identified in individual CPFs. Training events and expert missions were held both in person and on-line. More than 200 requisitions for procurement of equipment were processed to support priority infrastructure upgrades.

In March, National Liaison Officers (NLOs) and National Liaison Assistants (NLAs) participated in a biennial meeting at which the regional proposals for the 2020–2022 technical cooperation cycle were discussed and prioritized, and 15 new regional projects and 78 national projects were submitted for the approval of the Agency's Board of Governors in November.

At the annual NLO meeting, participants agreed to begin work to update the Europe Regional Profile. The exercise will define common needs and priorities in the region that could be addressed using nuclear technologies, and will guide the development of regional projects in the medium term. A working group with Member State representatives was established to lead the revision, and a draft has been prepared which will be finalized in 2022.

Latin America and the Caribbean

In a milestone for the Caribbean region, a Steering Committee was established for the Regional Strategic Framework (RSF) for Technical Cooperation with IAEA–CARICOM Member States, with the participation of NLOs, NLAs and regional organizations. The Steering Committee will monitor progress in the implementation of the RSF through the technical cooperation programme towards the achievement of the stated regional priorities.

The States party to the Regional Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean (ARCAL) and the Agency have supported the establishment of a new regional chapter of Women in Nuclear (WiN) for Latin America and the Caribbean, which was inaugurated at a side event during the 65th regular session of the Agency's General Conference. The new WiN chapter will support the equal participation of women in nuclear science and technology by promoting their contribution to technical, scientific and leadership roles in the field.

Dominique Mouillot, President of WiN Global, speaking at the WiN ARCAL side event at the Agency's General Conference.

Programme of Action for Cancer Therapy (PACT)

ImPACT (integrated missions of PACT) Review missions were conducted jointly with the International Agency for Research on Cancer (IARC) and the World Health Organization (WHO) in the Democratic Republic of the Congo, Iraq, Nepal and Uruguay, while follow-up reviews to support implementation were conducted in Honduras and Jamaica. Reviews were initiated in Colombia, the Syrian Arab Republic and Uzbekistan. PACT facilitated support to Sri Lanka to prepare a radiotherapy plan.

Workshops and webinars supported the sharing of Member States' good practices on cancer control efforts, with a view to strengthening South–South cooperation on cancer control. At a donor roundtable in June, key supporters and advocates of the Agency's work on cancer discussed ongoing activities and outstanding funding needs.

Ten countries began receiving expert advisory support from the Agency, IARC and WHO to develop comprehensive national cancer control plans (NCCPs). In one country, the three organizations contributed to a mid-term review of the NCCP. Five countries received technical assistance to develop bankable documents. Under the Women's Cancers Partnership Initiative with the Islamic Development Bank (IsDB), a bankable document from Uzbekistan was approved by the IsDB for financing in the amount of approximately €71.2 million. A bankable document from Chad developed with Agency technical assistance was approved by the Kuwait Fund for Arab Economic Development for financing in the amount of €19.6 million.

Experts from the Agency, IARC and WHO reviewed Uruguay's cancer services to provide advice to the Government on tackling the country's growing cancer burden.

Strengthening the Quality of the Technical Cooperation Programme

In 2021, the Agency reviewed the projects designed and proposed for the 2022–2023 technical cooperation programme, using a country-portfolio approach that emphasized the links between technical cooperation project design and CPFs to align planning and design and reinforce monitoring.

The submission rate of Project Progress Assessment Reports (PPARs) for the 2020 reporting period increased to 82%, up from 71% in the preceding year. The submission of PPARs provides an opportunity to record project progress towards achieving outputs and outcomes.

Knowledge management and training were improved in 2021: processes for staff induction, orientation, handover and peer knowledge sharing were enhanced. To support effective technical cooperation procurement, guidance for counterparts and end users, describing their roles and responsibilities in the procurement process, was issued.

Outreach and Communication

Over 170 web stories on technical cooperation were published. Social media channels remained an important cost-free means of communicating on a wide range of Agency development activities, and new outreach materials were issued, including *The IAEA Technical Cooperation Programme: Selected Highlights 2020*.

Two virtual seminars on technical cooperation were held for the diplomatic communities in Berlin, Brussels, Geneva and Paris, and in New York. The seminars aimed to raise awareness of the technical cooperation programme and its contribution to Member State development priorities, including achievement of the SDGs.

Four technical cooperation side events were organized during the 65th regular session of the General Conference: 'Enhancing Human Resource Development in Nuclear Science and Technology', 'The Technical Cooperation Programme in Asia and the Pacific: Major Contribution to Development', 'Developing Capacity for the Wider Use of Stable Isotope Techniques for Source Attribution of Greenhouse Gases in the Atmosphere', and 'Inauguration of the Women in Nuclear ARCAL Regional Chapter'.

Technical Cooperation outreach in 2021

172 Agency web articles on technical cooperation

7082 @IAEATC Twitter followers and
464 tweets posted (up from 360 in 2020)

2254 @iaeapact Twitter followers and
409 tweets

4356 LinkedIn followers

1682 LinkedIn TC Alumni Group members

Cooperation with the United Nations System

In January, the Agency held a side event entitled 'Nuclear Science and Technology for Climate Change Adaptation' at the Climate Adaptation Summit 2021, and engaged extensively through side events and social media outreach during the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change in November in Glasgow, United Kingdom.

The Agency organized side events at the United Nations Multi-stakeholder Forum on Science, Technology and Innovation for the SDGs ('From COVID-19 Emergency Response to Integrated Action to Address Zoonotic Diseases') and at the United Nations High-Level Political Forum on Sustainable Development ('Nuclear Science and Technology in Support of Integrated Actions to Enhance Countries Post-Pandemic Recovery'). Together with the World Food Programme and the United Nations Population Fund, the Agency took part in a side event at the 76th session of the United Nations General Assembly on COVID-19 response and approaches to strengthen health systems.

The Agency participated in the United Nations Department of Economic and Social Affairs (UNDESA) Second Open Call for SDG Good Practices, Success Stories and Lessons Learned, submitting seven SDG Good Practices related to the Agency's support to Member States in a variety of areas. All seven SDG Good Practices are now available on the UNDESA website.

Partnership Agreements and Practical Arrangements

The Agency concluded several new partnerships related to technical cooperation in 2021, with the Global Plastic Action Partnership (GPAP), the World Meteorological Organization (WMO), the China International Development Cooperation Agency (CIDCA), the Pakistan Atomic Energy Commission (PAEC), the City Cancer Challenge (C/Can) and the Spanish Society of Radiological Protection (SEPR). One existing partnership, with Enresa, was extended, with the aim of building on the results achieved and continuing joint work in the area of radioactive waste management.

The GPAP brings together governments, businesses and civil society to translate commitments into meaningful action at global and national levels to free the world from plastic waste and pollution. As an affiliate member, the Agency will collaborate with GPAP on the operationalization of the Nuclear Technology for Controlling Plastic Pollution (NUTEC Plastics) initiative.

An agreement between WMO and the Agency was finalized in 2021 and signed in January 2022. The two organizations pledged to work together in combating the effects of climate change and pollution in the framework of interregional technical cooperation project 'Developing Capacity Towards the Wider Use of Stable Isotopic Techniques for Source Attribution of Greenhouse Gases in the Atmosphere'.

The Agency joined forces with the CIDCA to scale up action to support developing countries in the achievement of the SDGs, and to strengthen South–South and triangular cooperation. The agreement is also expected to support the implementation of NUTEC Plastics and the Zoonotic Disease Integrated Action (ZODIAC) initiatives.

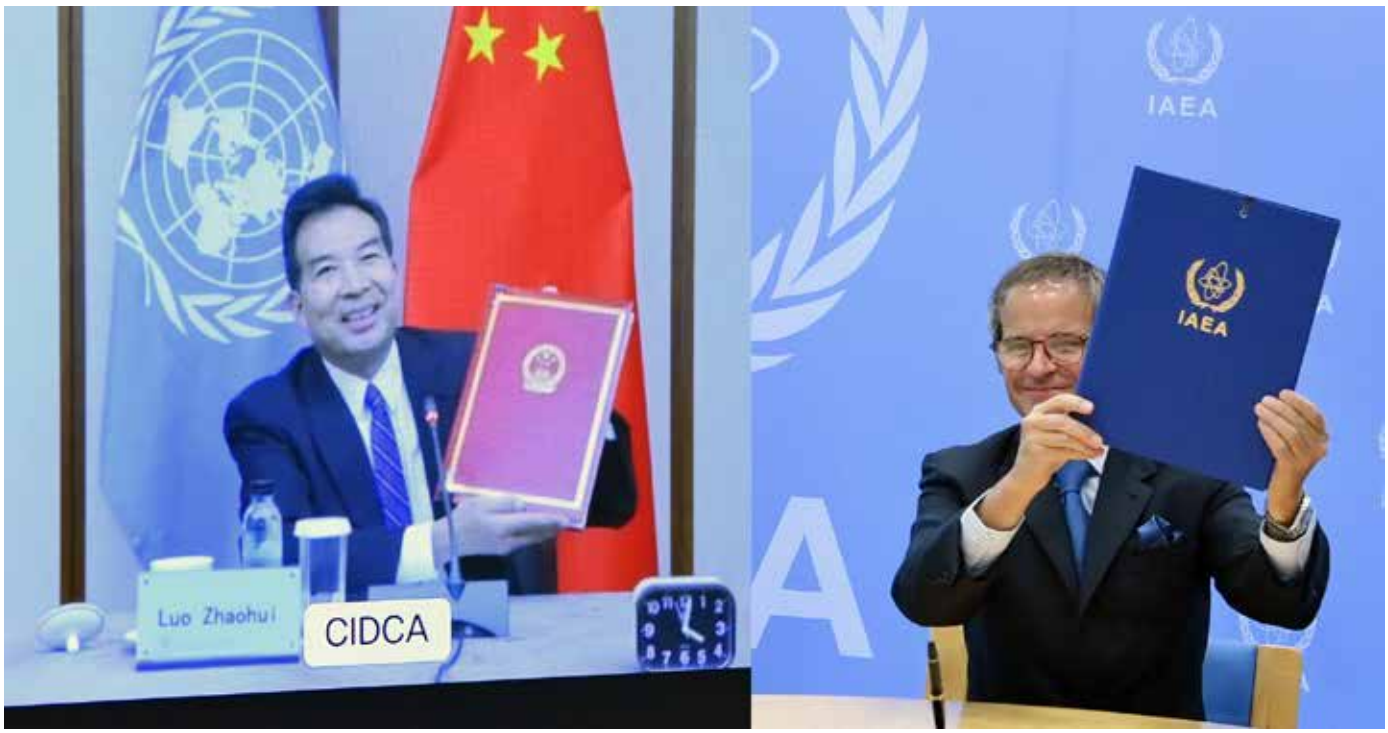
The Agency and the PAEC signed Practical Arrangements that will enable regulators and users of nuclear technology from Africa and Asia and the Pacific to benefit from PAEC's long-standing experience in managing nuclear power and nuclear technology projects.

The Agency and C/Can entered into partnership for the benefit of cancer patients in cities in low and middle income countries, focusing on improving access to quality radiation medicine.

Practical Arrangements were signed with the SEPR to enhance cooperation in radiological protection.

Activities and actions under existing agreements

Two joint regional projects on food safety and climate resilient agriculture have been developed under existing Practical Arrangements between the Agency and the United Nations Industrial Development Organization. Efforts are ongoing to mobilize resources for both projects.



A Memorandum of Understanding with the CIDCA, the first of its kind between the Agency and a national development or aid institute, was signed on 14 October.

The Practical Arrangements for triangular cooperation signed between Cambodia, the Lao People's Democratic Republic and Viet Nam supported virtual training events organized by Viet Nam for Cambodian institutions on radiation protection and safety, the industrial application of radiation processing and non-destructive testing. The Arrangements also supported fellowships in Viet Nam for trainees from the Lao People's Democratic Republic.

Through imPACT Reviews, NCCP advisory support and follow-ups to cancer assessments, the Agency works with IARC and WHO to address cancer comprehensively. During the annual consultation between the three agencies, efforts to increase synergies in cancer control assessments, streamline data collection and collaborate on resource mobilization efforts were advanced. The Agency, through PACT, continued to work with the Global Access to Cancer Care Foundation, the Union for International Cancer Control and the Joint United Nations Programme on HIV/AIDS to implement existing partnerships.

Legislative Assistance

The Agency continued to provide legislative assistance to Member States through workshops, missions and meetings to raise awareness, advise and train on developing and revising national legislation and adhering to and implementing the relevant international legal instruments. Seven Member States received country specific bilateral legislative assistance through written comments and advice on drafting national nuclear legislation. As an on-line alternative to some in-person activities and as a follow-up to reviews of legislation, 12 virtual activities on different aspects of nuclear law were held for Armenia, Botswana, Colombia, Côte d'Ivoire, Croatia, Indonesia, Jordan, Mali, Paraguay, Sri Lanka, Türkiye and Viet Nam. In addition, two targeted virtual workshops on nuclear law provided diplomats and officials from permanent missions located in Berlin, Brussels, Geneva, Paris and New York with a high-level overview of international and national nuclear law and the Agency's role in the development and implementation of nuclear law including assistance provided through the legislative assistance programme. Further,

three regional and sub-regional workshops on nuclear law were held for English-speaking Member States in Africa and in Latin America and the Caribbean, and for French-speaking Member States in Africa.

Owing to COVID-19 related restrictions, the 2021 session of the annual Nuclear Law Institute interregional training event had to be postponed until 2022. Building on a series of interactive webinars on nuclear law held in 2021, the Agency launched a new series of webinars focused on topical issues in nuclear law. During 2021, planning was under way for the Agency's First International Conference on Nuclear Law: The Global Debate, which is scheduled to take place at Headquarters in 2022.

Treaty Event

The annual Treaty Event took place during the 65th regular session of the General Conference, providing Member States with an additional opportunity to deposit their instruments of ratification, acceptance, or approval of, or of accession to, the multilateral treaties deposited with the Director General. The event focused on the multilateral treaties relating to nuclear safety and security and to civil liability for nuclear damage.

CASE STUDY

Improved Aquifer Management in Namibia

Groundwater provides half of all drinking water worldwide. The impact of climate change on groundwater sources severely impacts the availability and quality of water in many countries, including Namibia. With a drought emergency declared in 2019 and increasingly extreme weather conditions in recent years, annual rainfall may no longer be sufficient to replenish groundwater resources, according to experts. The growing influx of people living in and moving to Namibia's capital, Windhoek, as well as to coastal cities, is contributing to the country's struggle to maintain water supplies.

The Agency, Namibia's Ministry of Agriculture, Water and Land Reform, and Germany's Federal Institute for Geosciences and Natural Resources have collaborated to investigate Namibia's water resources, in order to protect them and ensure that water supplies are sufficient all-year-round. The project uses isotopes which reveal information about the nature, history and flow of water, enabling an assessment of water variability in aquifers.

"Using isotopes to assess our groundwater resources is of extreme importance for maintaining reliable sources of water throughout the country," said Anna Kaupuko David, a hydrogeologist at Namibia's Ministry of Agriculture, Water and Land Reform. "If we suffer from a drought, the Windhoek aquifer becomes our emergency water supply for the city and can last at least three years. However, it is unclear how using the aquifer in this way would impact its future."

Namibia, the driest African country south of the Sahara Desert, is prone to droughts and suffers from limited freshwater resources.

Analysing the evolution of the country's rain distribution during the rainy summer season and the dry winter season through isotopes has indicated how the availability of groundwater can be altered in cases of drought due to climate change. Through this improved knowledge of groundwater dynamics, experts in Namibia can manage water resources better and avoid water emergencies such as the 2019 drought.

An on-line training course launched in May 2021 helped participants to understand how isotopes can be used to accurately assess and manage groundwater. "The training session taught us how to plan our field trips and collect samples of stable isotopes, as well as considerations and equipment needed to collect good quality samples for analysis," said Kaupuko David.

The study began by taking samples from the Kuiseb aquifer, a groundwater source that is under extreme stress from supplying water to the growing cities of Walvis Bay and Swakopmund. Results from these samples will be used to predict the future impact of climate change on national groundwater resources and to guide protection and governance activities.

"The use of isotopes is an area of great importance in adapting to climate change. Through technical assistance and targeted capacity building, the Agency is continuously building partnerships and bridges to coordinate responses to drought emergencies and to ensure that countries are able to manage water resources in a sustainable way," said Anna Grigoryan, the Agency's Programme Management Officer coordinating activities in Namibia.

CASE STUDY

Global Support for Nuclear-derived COVID-19 Testing Equipment, Supplies and Training

At the request of governments from all over the world, the Agency has delivered COVID-19 testing support and equipment to 305 laboratories in 129 countries and territories for the rapid and accurate detection of the disease. The deliveries began in 2020 and continued in 2021, with additional funding of approximately €3.5 million allotted and further countries such as Samoa and Suriname receiving support.

"The impact of our work to save lives and livelihoods has helped millions of people so far. By helping countries in need through providing necessary equipment, we have helped protect the wider international community," said the Agency's Director General, Rafael Mariano Grossi.

The Agency's assistance helps countries boost their use of real time reverse transcription–polymerase chain reaction (RT–PCR) tests – the most accurate and widely used method to detect specific genetic material from pathogens, including viruses. PCR is a nuclear-derived method whose use has been supported by the Agency, in collaboration with the Food and Agriculture Organization of the United Nations (FAO), for detecting animal viruses for decades.

The COVID-19 assistance is the biggest emergency operation in the Agency's history. Agency assistance is delivered through an interregional technical cooperation project

The Agency is dispatching equipment to countries and territories around the world to enable them to use a nuclear-derived technique to rapidly detect the coronavirus that causes COVID-19. (Photograph courtesy of the Scientific Research Organisation of Samoa.)

established as part of the 2020–2021 technical cooperation programme, designed to respond to countries' needs in the event of disease outbreaks, emergencies and disasters. Along with equipment, the Agency is providing testing reagents and consumables to laboratories to perform RT–PCR tests. Items include biosafety supplies, such as personal protective equipment and laboratory cabinets to ensure the safe handling, storage and analysis of collected samples.

The Agency is also providing technical guidance and advice for health and laboratory professionals through webinars and videos on-line. Topics covered include guidance on establishing molecular diagnostic laboratories, assessment of required equipment, and quality control measures to ensure samples are appropriately collected, stored and analysed.

Additionally, through a COVID-19-related webinar for health care providers at nuclear medicine and radiology facilities, the Agency helped health professionals adjust their standard operating procedures and minimize the risks of infection from the virus among patients, staff and the public.

During 2021, the Agency, through the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, provided guidance and information on COVID-19 detection to medical and veterinary laboratories, including standard operating procedures to identify the virus in line with World Health Organization (WHO) guidelines. The Agency is also part of the WHO-led COVID-19 Crisis Management Team, comprising 14 United Nations entities.

Annex

Note: Tables A30–A35 are available on-line only at *www.iaea.org/publications/reports.*

Table A1. Regular Budget allocation and utilization of resources in 2021 by Programme and Major Programme (in euros)

Major Programme (MP)/Programme	Original budget US$1/€1	Adjusted budget US$1/€0.843	Expenditure	Resource utlization	Balances
	a*	b**	c	d = c/b	e = b - c
MP1 — Nuclear Power, Fuel Cycle and Nuclear Science					
Overall management, coordination and common activities	3 360 351	3 282 333	3 344 565	101.9%	(62 232)
Nuclear Power	9 239 624	8 987 895	8 535 574	95.0%	452 321
Nuclear Fuel Cycle and Waste Management	7 914 211	7 711 745	7 691 997	99.7%	19 748
Capacity Building and Nuclear Knowledge for Sustainable Energy Development	10 925 073	10 648 368	10 370 801	97.4%	277 567
Nuclear Science	10 636 040	10 446 970	10 265 623	98.3%	181 347
Total Major Programme 1	**42 075 299**	**41 077 311**	**40 208 560**	**97.9%**	**868 751**
MP2 — Nuclear Techniques for Development and Environmental Protection					
Overall management, coordination and common activities	8 413 869	8 312 964	8 651 584	104.1%	(338 620)
Food and Agriculture	12 258 340	12 043 593	12 140 727	100.8%	(97 134)
Human Health	8 989 368	8 787 823	8 759 511	99.7%	28 312
Water Resources	3 813 179	3 748 462	4 091 657	109.2%	(343 195)
Environment	6 799 753	6 666 289	6 511 242	97.7%	155 047
Radioisotope Production and Radiation Technology	2 513 403	2 468 027	1 850 838	75.0%	617 189
Total Major Programme 2	**42 787 912**	**42 027 158**	**42 005 559**	**99.9%**	**21 599**
MP3 — Nuclear Safety and Security					
Overall management, coordination and common activities	4 147 204	4 038 093	4 178 164	103.5%	(140 071)
Incident and Emergency Preparedness and Response	4 539 719	4 427 103	4 295 170	97.0%	131 933
Safety of Nuclear Installations	10 874 184	10 552 819	10 031 321	95.1%	521 498
Radiation and Transport Safety	7 787 516	7 570 720	7 652 185	101.1%	(81 465)
Radioactive Waste Management and Environmental Safety	3 927 320	3 822 584	3 867 982	101.2%	(45 398)
Nuclear Security	6 406 666	6 200 369	6 384 313	103.0%	(183 944)
Total Major Programme 3	**37 682 609**	**36 611 688**	**36 409 135**	**99.4%**	**202 553**
MP4 — Nuclear Verification					
Overall management, coordination and common activities	14 351 436	14 119 449	14 330 527	101.5%	(211 078)
Safeguards Implementation	133 500 420	130 123 587	129 870 374	99.8%	253 213
Other Verification Activities	3 236 900	3 113 290	3 105 722	99.8%	7 568
Total Major Programme 4	**151 088 756**	**147 356 326**	**147 306 623**	**100.0%**	**49 703**
MP5 — Policy, Management and Administration Services					
Policy, Management and Administration Services	82 678 999	81 351 044	81 350 113	100.0%	931
Total Major Programme 5	**82 678 999**	**81 351 044**	**81 350 113**	**100.0%**	**931**
MP6 — Management of Technical Cooperation for Development					
Management of Technical Cooperation for Development	26 731 414	26 250 394	25 519 686	97.2%	730 708
Total Major Programme 6	**27 159 116**	**26 530 211**	**26 529 940**	**100.0%**	**271**
Total Operational Regular Budget	**383 472 691**	**374 953 738**	**373 809 930**	**99.7%**	**1 143 808**
Major Capital Investment Funding Requirements* **					
MP1 — Nuclear Power, Fuel Cycle and Nuclear Science	–	–	–	0.0%	–
MP2 — Nuclear Techniques for Development and Environmental Protection	2 066 544	2 063 407	-	0.0%	2 063 407
MP3 — Nuclear Safety and Security	309 982	309 982	6 829	2.2%	303 153
MP4 — Nuclear Verification	1 033 272	1 033 272	-	0.0%	1 033 272
MP5 — Policy, Management and Administration Services	2 789 834	2 789 834	455 622	16.3%	2 334 212
MP6 — Management of Technical Cooperation for Development	–	–	–	0.0%	–
Total Capital Regular Budget	**6 199 632**	**6 196 495**	**462 451**	**7.5%**	**5 734 044**
Total Agency Programmes	**389 672 323**	**381 150 233**	**374 272 381**	**98.2%**	**6 877 852**
Reimbursable Work for Others	3 179 422	3 179 422	3 280 134	103.2%	(100 712)
Total Regular Budget	**392 851 745**	**384 329 655**	**377 552 515**	**98.2%**	**6 777 140**

* General Conference Resolutions GC(63)/RES/5 of September 2020 original budget at US $1/€1.
** Original Budget revalued at the United Nations operational average rate of exchange of €0.843 to $1.
*** Additional information about the Major Capital Investment Fund can be found in note 39d of *The Agency's Financial Statements for 2021.*

Table A2. Extrabudgetary regular programme fund resource utilization in 2021 by Programme and Major Programme (in euros)

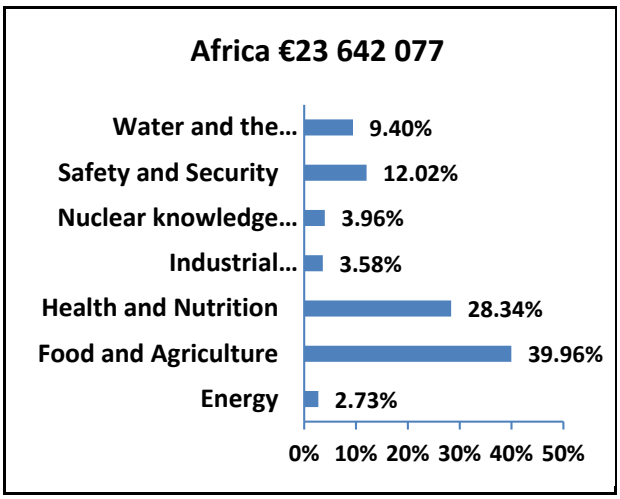
Major Programme (MP)/Programme	2021 net expenditure
MP1 — Nuclear Power, Fuel Cycle and Nuclear Science	
Overall management, coordination and common activities	102 169
Nuclear Power	2 866 813
Nuclear Fuel Cycle and Waste Management	1 796 205
Capacity Building and Nuclear Knowledge for Sustainable Energy Development	2 524 144
Nuclear Science	5 842 721
Total Major Programme 1	**13 132 052**
MP2 — Nuclear Techniques for Development and Environmental Protection	
Overall management, coordination and common activities	3 515 658
Food and Agriculture	5 403 039
Human Health	381 626
Water Resources	-
Environment	1 221 902
Radioisotope Production and Radiation Technology	267 909
Total Major Programme 2	**10 790 134**
MP3 — Nuclear Safety and Security	
Overall management, coordination and common activities	2 835 840
Incident and Emergency Preparedness and Response	523 036
Safety of Nuclear Installations	3 403 577
Radiation and Transport Safety	919 496
Radioactive Waste Management and Environmental Safety	805 081
Nuclear Security	25 258 525
Total Major Programme 3	**33 745 555**
MP4 — Nuclear Verification	
Overall management, coordination and common activities	1 374 422
Safeguards Implementation	17 433 925
Other Verification Activities	4 023 306
Total Major Programme 4	**22 831 653**
MP5 — Policy, Management and Administration Services	
Policy, Management and Administration Services	3 189 111
Total Major Programme 5	**3 189 111**
MP6 — Management of Technical Cooperation for Development	
Management of Technical Cooperation for Development	773 359
Total Major Programme 6	**773 359**
Total extrabudgetary programme funds	**84 461 864**

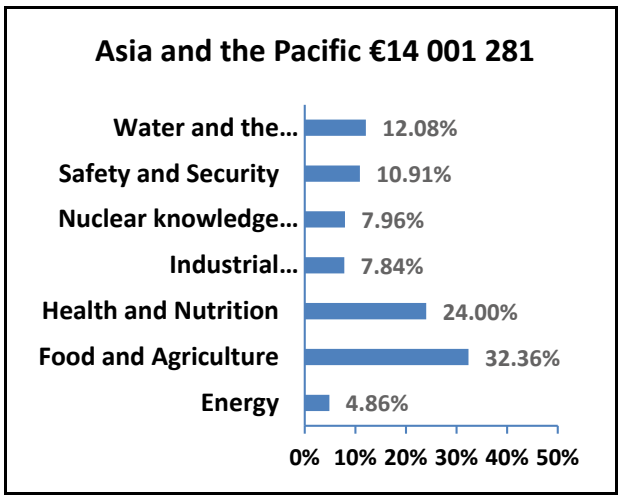
Table A3(a). Disbursements (actuals) of the Technical Cooperation Fund by technical field and region in 2021

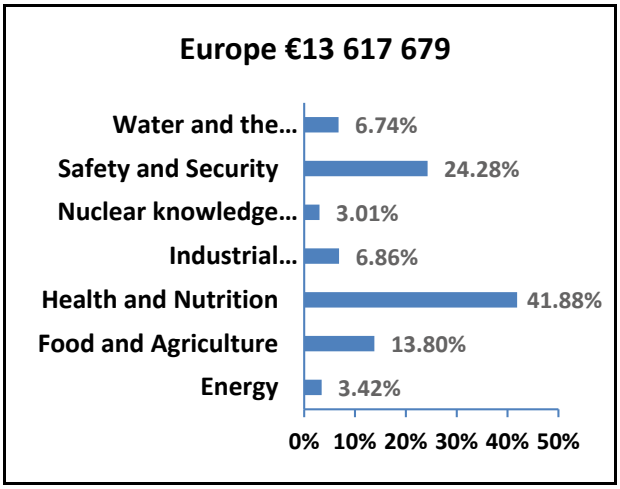
Summary of all regions (in euros)							
Technical field	**Africa**	**Asia and the Pacific**	**Europe**	**Latin America and the Caribbean**	**Interregional and miscellaneous**	**PACT[a]**	**Grand total**
Energy	644 410	680 785	465 543	154 715	528 717	0	**2 474 170**
Food and Agriculture	9 448 542	4 530 949	1 879 711	3 392 045	402 798	0	**19 654 046**
Health and Nutrition	6 701 112	3 360 030	5 702 978	5 086 695	262 656	215 182	**21 328 652**
Industrial Applications/ Radiation Technology	846 459	1 097 046	934 324	1 162 733	0	0	**4 040 562**
Nuclear knowledge development and management	936 836	1 113 858	410 349	1 146 554	13 732 233	0	**17 339 831**
Safety and Security	2 842 570	1 527 787	3 306 464	1 910 062	451 574	0	**10 038 457**
Water and the Environment	2 222 146	1 690 824	918 310	1 667 815	1 500	0	**6 500 595**
Grand Total	**23 642 077**	**14 001 281**	**13 617 679**	**14 520 618**	**15 379 477**	**215 182**	**81 376 314**

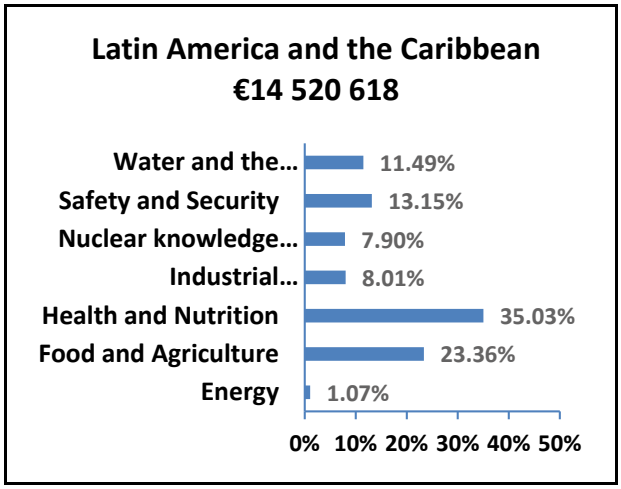
[a] PACT: Programme of Action for Cancer Therapy.

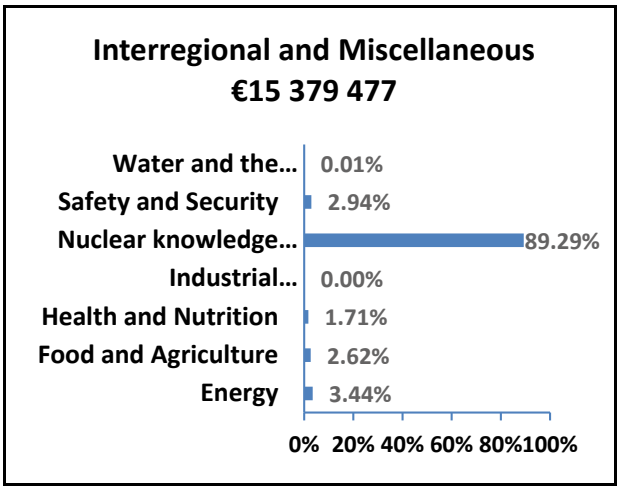
Table A3(b). Graphical representation of the information in Table A3(a)

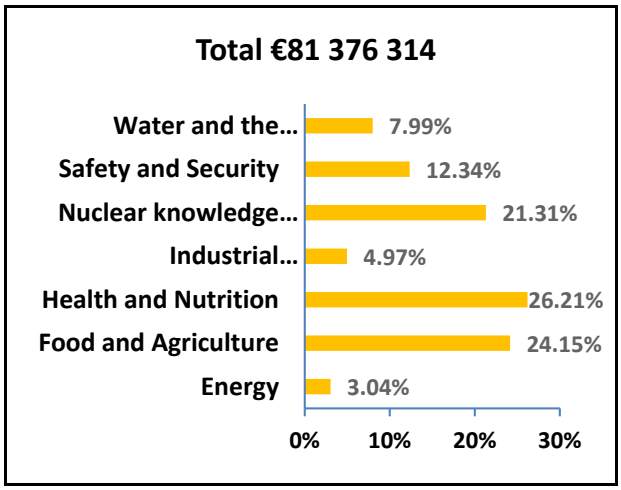












Note: See Table A3(a) for the full titles of the technical fields.

Table A4. Amount of nuclear material under Agency safeguards at the end of 2021 by type of agreement

Nuclear material	Comprehensive safeguards agreement[a]	INFCIRC/66-type agreement	Voluntary offer agreement	Quantity in significant quantities (SQs)
Plutonium[b] contained in irradiated fuel and in fuel elements in reactor cores	151 374	3 479	21 934	176 787
Separated plutonium outside reactor cores	1 257	5	10 892	12 154
High enriched uranium (equal to or greater than 20% U-235)	154	2	0	156
Low enriched uranium (less than 20% U-235)	19 314	403	1 158	20 875
Source material[c] (natural and depleted uranium and thorium)	11 808	1 728	2 590	16 126
U-233	18	0	0	18
Total SQs of nuclear material	**183 925**	**5 617**	**36 574**	**226 116**

Amount of heavy water under Agency safeguards at the end of 2021 by type of agreement

Non-nuclear material[d]	Comprehensive safeguards agreement	INFCIRC/66-type agreement	Voluntary offer agreement	Quantity in tonnes
Heavy water (tonnes)		**418.7**		**419.4[e]**

[a] Includes nuclear material under Agency safeguards in Taiwan, China; excludes nuclear material in the Democratic People's Republic of Korea.

[b] The quantity includes an estimated amount (9 000 SQs) of plutonium in fuel elements loaded into reactor cores and plutonium in other irradiated fuel, which has not yet been reported to the Agency under agreed reporting procedures.

[c] This table does not include material within the terms of subparagraphs 34(a) and 34(b) of INFCIRC/153 (Corrected).

[d] Non-nuclear material subject to Agency safeguards under INFCIRC/66/Rev.2-type agreements.

[e] Includes 0.7 tonnes of heavy water under Agency safeguards in Taiwan, China.

Table A5. Number of facilities and material balance areas outside facilities under Agency safeguards during 2021

Type	Comprehensive safeguards agreement[a]	INFCIRC/66-type agreement[b]	Voluntary offer agreement	Total
Power reactors	246	17	1	**264**
Research reactors and critical assemblies	143	3	1	**147**
Conversion plants	17	0	0	**17**
Fuel fabrication plants	37	3	1	**41**
Reprocessing plants	10	0	1	**11**
Enrichment plants	16	0	3	**19**
Separate storage facilities	136	2	4	**142**
Other facilities	77	0	0	**77**
Facility subtotals	**682**	**25**	**11**	**718**
Material balance areas containing locations outside facilities[c]	615	1	0	**616**
Total	**1297**	**26**	**11**	**1334**

[a] Covering safeguards agreements pursuant to the Treaty on the Non-Proliferation of Nuclear Weapons and/or the Treaty of Tlatelolco and other comprehensive safeguards agreements; includes facilities in Taiwan, China.

[b] Covering facilities in India, Israel and Pakistan.

[c] Includes 72 material balance areas in States with amended small quantities protocols.

Table A6. Conclusion of safeguards agreements, additional protocols and small quantities protocols (status as of 31 December 2021)

State [a]	Small quantities protocols [b]	Safeguards agreements [c]	INFCIRC	Additional protocols
Afghanistan	Amended: 28 Jan. 2016	In force: 20 Feb. 1978	257	In force: 19 Jul. 2005
Albania[1]		In force: 25 Mar. 1988	359	In force: 3 Nov. 2010
Algeria		In force: 7 Jan. 1997	531	Signed: 16 Feb. 2018
Andorra	Amended: 24 Apr. 2013	In force: 18 Oct. 2010	808	In force: 19 Dec. 2011
Angola	In force: 28 Apr. 2010	In force: 28 Apr. 2010	800	In force: 28 Apr. 2010
Antigua and Barbuda[2]	Amended: 5 Mar. 2012	In force: 9 Sep. 1996	528	In force: 15 Nov. 2013
Argentina[3]		In force: 4 Mar. 1994	435	
Armenia		In force: 5 May 1994	455	In force: 28 Jun. 2004
Australia		In force: 10 Jul. 1974	217	In force: 12 Dec. 1997
Austria[4]		Accession: 31 Jul. 1996	193	In force: 30 Apr. 2004
Azerbaijan		In force: 29 Apr. 1999	580	In force: 29 Nov. 2000
Bahamas[2]	Amended: 25 Jul. 2007	In force: 12 Sep. 1997	544	
Bahrain	In force: 10 May 2009	In force: 10 May 2009	767	In force: 20 Jul. 2011
Bangladesh		In force: 11 Jun. 1982	301	In force: 30 Mar. 2001
Barbados[2]	X	In force: 14 Aug. 1996	527	
Belarus		In force: 2 Aug. 1995	495	Signed: 15 Nov. 2005
Belgium		In force: 21 Feb. 1977	193	In force: 30 Apr. 2004
Belize[5]	Amended: 21 Jun. 2021	In force: 21 Jan. 1997	532	
Benin	Amended: 17 Sep. 2019	In force: 17 Sep. 2019	930	In force: 17 Sep. 2019
Bhutan	X	In force: 24 Oct. 1989	371	
Bolivia, Plurinational State of [2]	X	In force: 6 Feb. 1995	465	Signed: 18 Sep. 2019
Bosnia and Herzegovina		In force: 4 Apr. 2013	851	In force: 3 Jul. 2013
Botswana		In force: 24 Aug. 2006	694	In force: 24 Aug. 2006
Brazil[6]		In force: 4 Mar. 1994	435	
Brunei Darussalam	Amended: 2 Sep. 2021	In force: 4 Nov. 1987	365	
Bulgaria[7]		Accession: 1 May 2009	193	Accession: 1 May 2009
Burkina Faso	Amended: 18 Feb. 2008	In force: 17 Apr. 2003	618	In force: 17 Apr. 2003

State [a]	Small quantities protocols [b]	Safeguards agreements [c]	INFCIRC	Additional protocols
Burundi	In force: 27 Sep. 2007	In force: 27 Sep. 2007	719	In force: 27 Sep. 2007
Cabo Verde	*Amended: 27 Mar. 2006*	*Signed: 28 Jun. 2005*		*Signed: 28 Jun. 2005*
Cambodia	Amended: 16 Jul. 2014	In force: 17 Dec. 1999	586	In force: 24 Apr. 2015
Cameroon	Amended: 15 Jul. 2019	In force: 17 Dec. 2004	641	In force: 29 Sep. 2016
Canada		In force: 21 Feb. 1972	164	In force: 8 Sep. 2000
Central African Republic	In force: 7 Sep. 2009	In force: 7 Sep. 2009	777	In force: 7 Sep. 2009
Chad	In force: 13 May 2010	In force: 13 May 2010	802	In force: 13 May 2010
Chile[8]		In force: 5 Apr. 1995	476	In force: 3 Nov. 2003
China		In force: 18 Sep. 1989	369*	In force: 28 Mar. 2002
Colombia[8]		In force: 22 Dec. 1982	306	In force: 5 Mar. 2009
Comoros	In force: 20 Jan. 2009	In force: 20 Jan. 2009	752	In force: 20 Jan. 2009
Congo	In force: 28 Oct. 2011	In force: 28 Oct. 2011	831	In force: 28 Oct. 2011
Costa Rica[2]	Amended: 12 Jan. 2007	In force: 22 Nov. 1979	278	In force: 17 Jun. 2011
Côte d'Ivoire		In force: 8 Sep. 1983	309	In force: 5 May 2016
Croatia[9]		Accession: 1 Apr. 2017	193	Accession: 1 Apr. 2017
Cuba[2]		In force: 3 Jun. 2004	633	In force: 3 Jun. 2004
Cyprus[10]		Accession: 1 May 2008	193	Accession: 1 May 2008
Czech Republic[11]		Accession: 1 Oct. 2009	193	Accession: 1 Oct. 2009
Democratic Republic of the Congo		In force: 9 Nov. 1972	183	In force: 9 Apr. 2003
Denmark[12]		In force: 1 Mar. 1972 In force: 21 Feb. 1977	176 193	In force: 22 Mar. 2013 In force: 30 Apr. 2004
Djibouti	In force: 26 May 2015	In force: 26 May 2015	884	In force: 26 May 2015
Dominica[5]	X	In force: 3 May 1996	513	
Dominican Republic[2]	Amended: 11 Oct. 2006	In force: 11 Oct. 1973	201	In force: 5 May 2010
Democratic People's Republic of Korea		In force: 10 Apr. 1992	403	
Ecuador[2]	Amended: 7 Apr. 2006	In force: 10 Mar. 1975	231	In force: 24 Oct. 2001
Egypt		In force: 30 Jun. 1982	302	
El Salvador[2]	Amended: 10 Jun. 2011	In force: 22 Apr. 1975	232	In force: 24 May 2004

State [a]	Small quantities protocols [b]	Safeguards agreements [c]	INFCIRC	Additional protocols
Equatorial Guinea	*Approved: 13 Jun. 1986*	*Approved: 13 Jun. 1986*		
Eritrea	In force: 20 Apr. 2021	In force: 20 Apr. 2021	960	In force: 20 Apr. 2021
Estonia[13]		Accession: 1 Dec. 2005	193	Accession: 1 Dec. 2005
Eswatini	Amended: 23 Jul. 2010	In force: 28 Jul. 1975	227	In force: 8 Sep. 2010
Ethiopia	Amended: 2 Jul. 2019	In force: 2 Dec. 1977	261	In force: 18 Sep. 2019
Fiji	X	In force: 22 Mar. 1973	192	In force: 14 Jul. 2006
Finland[14]		Accession: 1 Oct. 1995	193	In force: 30 Apr. 2004
France	Amended: 25 Feb. 2019	In force: 12 Sep. 1981 In force: 26 Oct. 2007[15]	290* 718	In force: 30 Apr. 2004
Gabon	Amended: 30 Oct. 2013	In force: 25 Mar. 2010	792	In force: 25 Mar. 2010
Gambia	Amended: 17 Oct. 2011	In force: 8 Aug. 1978	277	In force: 18 Oct. 2011
Georgia		In force: 3 Jun. 2003	617	In force: 3 Jun. 2003
Germany[16]		In force: 21 Feb. 1977	193	In force: 30 Apr. 2004
Ghana		In force: 17 Feb. 1975	226	In force: 11 Jun. 2004
Greece[17]		Accession: 17 Dec. 1981	193	In force: 30 Apr. 2004
Grenada[2]	X	In force: 23 Jul. 1996	525	
Guatemala[2]	Amended: 26 Apr. 2011	In force: 1 Feb. 1982	299	In force: 28 May 2008
Guinea	*Signed: 13 Dec. 2011*	*Signed: 13 Dec. 2011*		*Signed: 13 Dec. 2011*
Guinea-Bissau	*Signed: 21 Jun. 2013*	*Signed: 21 Jun. 2013*		*Signed: 21 Jun. 2013*
Guyana[2]	X	In force: 23 May 1997	543	
Haiti[2]	Amended: 22 Jan. 2020	In force: 9 Mar. 2006	681	In force: 9 Mar. 2006
Holy See	Amended: 11 Sep. 2006	In force: 1 Aug. 1972	187	In force: 24 Sep. 1998
Honduras[2]	Amended: 20 Sep. 2007	In force: 18 Apr. 1975	235	In force: 17 Nov. 2017
Hungary[18]		Accession: 1 Jul. 2007	193	Accession: 1 Jul. 2007
Iceland	Amended: 15 Mar. 2010	In force: 16 Oct. 1974	215	In force: 12 Sep. 2003
India[19]		In force: 30 Sep. 1971 In force: 17 Nov. 1977 In force: 27 Sep. 1988 In force: 11 Oct. 1989 In force: 1 Mar. 1994 In force: 11 May 2009	211 260 360 374 433 754	In force: 25 Jul. 2014
Indonesia		In force: 14 Jul. 1980	283	In force: 29 Sep. 1999

State [a]	Small quantities protocols [b]	Safeguards agreements [c]	INFCIRC	Additional protocols
Iran, Islamic Republic of[20]		In force: 15 May 1974	214	Signed: 18 Dec. 2003
Iraq		In force: 29 Feb. 1972	172	In force: 10 Oct. 2012
Ireland		In force: 21 Feb. 1977	193	In force: 30 Apr. 2004
Israel		In force: 4 Apr. 1975	249/Add.1	
Italy		In force: 21 Feb. 1977	193	In force: 30 Apr. 2004
Jamaica[2]		In force: 6 Nov. 1978	265	In force: 19 Mar. 2003
Japan		In force: 2 Dec. 1977	255	In force: 16 Dec. 1999
Jordan		In force: 21 Feb. 1978	258	In force: 28 Jul. 1998
Kazakhstan		In force: 11 Aug. 1995	504	In force: 9 May 2007
Kenya	In force: 18 Sep. 2009	In force: 18 Sep. 2009	778	In force: 18 Sep. 2009
Kiribati	X	In force: 19 Dec. 1990	390	Signed: 9 Nov. 2004
Korea, Republic of		In force: 14 Nov. 1975	236	In force: 19 Feb. 2004
Kuwait	Amended: 26 Jul. 2013	In force: 7 Mar. 2002	607	In force: 2 Jun. 2003
Kyrgyzstan	X	In force: 3 Feb. 2004	629	In force: 10 Nov. 2011
Lao People's Democratic Republic	X	In force: 5 Apr. 2001	599	Signed: 5 Nov. 2014
Latvia[21]		Accession: 1 Oct. 2008	193	Accession: 1 Oct. 2008
Lebanon	Amended: 5 Sep. 2007	In force: 5 Mar. 1973	191	
Lesotho	Amended: 8 Sep. 2009	In force: 12 Jun. 1973	199	In force: 26 Apr. 2010
Liberia	In force: 10 Dec. 2018	In force: 10 Dec. 2018	927	In force: 10 Dec. 2018
Libya		In force: 8 Jul. 1980	282	In force: 11 Aug. 2006
Liechtenstein		In force: 4 Oct. 1979	275	In force: 25 Nov. 2015
Lithuania[22]		Accession: 1 Jan. 2008	193	Accession: 1 Jan. 2008
Luxembourg		In force: 21 Feb. 1977	193	In force: 30 Apr. 2004
Madagascar	Amended: 29 May 2008	In force: 14 Jun. 1973	200	In force: 18 Sep. 2003
Malawi	Amended: 29 Feb. 2008	In force: 3 Aug. 1992	409	In force: 26 Jul. 2007
Malaysia		In force: 29 Feb. 1972	182	Signed: 22 Nov. 2005
Maldives	Amended: 21 May 2021	In force: 2 Oct. 1977	253	
Mali	Amended: 18 Apr. 2006	In force: 12 Sep. 2002	615	In force: 12 Sep. 2002

State [a]	Small quantities protocols [b]	Safeguards agreements [c]	INFCIRC	Additional protocols
Malta[23]		Accession: 1 Jul. 2007	193	Accession: 1 Jul. 2007
Marshall Islands		In force: 3 May 2005	653	In force: 3 May 2005
Mauritania	Amended: 20 Mar. 2013	In force: 10 Dec. 2009	788	In force: 10 Dec. 2009
Mauritius	Amended: 26 Sep. 2008	In force: 31 Jan. 1973	190	In force: 17 Dec. 2007
Mexico[24]		In force: 14 Sep. 1973	197	In force: 4 Mar. 2011
Micronesia, Federated States of	In force: 1 Sep. 2021	In force: 1 Sep. 2021	962	
Monaco	Amended: 27 Nov. 2008	In force: 13 Jun. 1996	524	In force: 30 Sep. 1999
Mongolia	X	In force: 5 Sep. 1972	188	In force: 12 May 2003
Montenegro	In force: 4 Mar. 2011	In force: 4 Mar. 2011	814	In force: 4 Mar. 2011
Morocco		In force: 18 Feb. 1975	228	In force: 21 Apr. 2011
Mozambique	In force: 1 Mar. 2011	In force: 1 Mar. 2011	813	In force: 1 Mar. 2011
Myanmar	X	In force: 20 Apr. 1995	477	Signed: 17 Sep. 2013
Namibia	X	In force: 15 Apr. 1998	551	In force: 20 Feb. 2012
Nauru	X	In force: 13 Apr. 1984	317	
Nepal	X	In force: 22 Jun. 1972	186	
Netherlands	X	In force: 5 Jun. 1975[15] In force: 21 Feb. 1977	229 193	 In force: 30 Apr. 2004
New Zealand[25]	Amended: 24 Feb. 2014	In force: 29 Feb. 1972	185	In force: 24 Sep. 1998
Nicaragua[2]	Amended: 12 Jun. 2009	In force: 29 Dec. 1976	246	In force: 18 Feb. 2005
Niger		In force: 16 Feb. 2005	664	In force: 2 May 2007
Nigeria		In force: 29 Feb. 1988	358	In force: 4 Apr. 2007
North Macedonia	Amended: 9 Jul. 2009	In force: 16 Apr. 2002	610	In force: 11 May 2007
Norway		In force: 1 Mar. 1972	177	In force: 16 May 2000
Oman	X	In force: 5 Sep. 2006	691	
Pakistan		In force: 5 Mar. 1962 In force: 17 Jun. 1968 In force: 17 Oct. 1969 In force: 18 Mar. 1976 In force: 2 Mar. 1977 In force: 10 Sep. 1991 In force: 24 Feb. 1993 In force: 22 Feb. 2007 In force: 15 Apr. 2011 In force: 3 May 2017	34 116 135 239 248 393 418 705 816 920	

State [a]	Small quantities protocols [b]	Safeguards agreements [c]	INFCIRC	Additional protocols
Palau	Amended: 15 Mar. 2006	In force: 13 May 2005	650	In force: 13 May 2005
Panama[8]	Amended: 4 Mar. 2011	In force: 23 Mar. 1984	316	In force: 11 Dec. 2001
Papua New Guinea	Amended: 6 Feb. 2019	In force: 13 Oct. 1983	312	
Paraguay[2]	Amended: 17 Jul. 2018	In force: 20 Mar. 1979	279	In force: 15 Sep. 2004
Peru[2]		In force: 1 Aug. 1979	273	In force: 23 Jul. 2001
Philippines		In force: 16 Oct. 1974	216	In force: 26 Feb. 2010
Poland[26]		Accession: 1 Mar. 2007	193	Accession: 1 Mar. 2007
Portugal[27]		Accession: 1 Jul. 1986	193	In force: 30 Apr. 2004
Qatar	In force: 21 Jan. 2009	In force: 21 Jan. 2009	747	
Republic of Moldova	Amended: 1 Sep. 2011	In force: 17 May 2006	690	In force: 1 Jun. 2012
Romania[28]		Accession: 1 May 2010	193	Accession: 1 May 2010
Russian Federation		In force: 10 Jun. 1985	327*	In force: 16 Oct. 2007
Rwanda	In force: 17 May 2010	In force: 17 May 2010	801	In force: 17 May 2010
Saint Kitts and Nevis[5]	Amended: 19 Aug. 2016	In force: 7 May 1996	514	In force: 19 May 2014
Saint Lucia[5]	Amended: 23 Nov. 2021	In force: 2 Feb. 1990	379	
Saint Vincent and the Grenadines[5]	X	In force: 8 Jan. 1992	400	
Samoa	X	In force: 22 Jan. 1979	268	
San Marino	Amended: 13 May 2011	In force: 21 Sep. 1998	575	
Sao Tome and Principe	*Approved: 21 Nov. 2019*	*Approved: 21 Nov. 2019*		*Approved: 21 Nov. 2019*
Saudi Arabia	X	In force: 13 Jan. 2009	746	
Senegal	Amended: 6 Jan. 2010	In force: 14 Jan. 1980	276	In force: 24 Jul. 2017
Serbia[29]		In force: 28 Dec. 1973	204	In force: 17 Sep. 2018
Seychelles	Amended: 31 Oct. 2006	In force: 19 Jul. 2004	635	In force: 13 Oct. 2004
Sierra Leone	X	In force: 4 Dec. 2009	787	Approved: 9 Jun. 2021
Singapore	Amended: 31 Mar. 2008	In force: 18 Oct. 1977	259	In force: 31 Mar. 2008
Slovakia[30]		Accession: 1 Dec. 2005	193	Accession: 1 Dec. 2005
Slovenia[31]		Accession: 1 Sep. 2006	193	Accession: 1 Sep. 2006
Solomon Islands	X	In force: 17 Jun. 1993	420	

State [a]	Small quantities protocols [b]	Safeguards agreements [c]	INFCIRC	Additional protocols
Somalia				
South Africa		In force: 16 Sep. 1991	394	In force: 13 Sep. 2002
Spain		Accession: 5 Apr. 1989	193	In force: 30 Apr. 2004
Sri Lanka		In force: 6 Aug. 1984	320	Approved: 12 Sep. 2018
State of Palestine[32]	*Signed: 14 Jun. 2019*	*Signed: 14 Jun. 2019*		
Sudan	Amended: 19 Feb. 2021	In force: 7 Jan. 1977	245	
Suriname[2]	X	In force: 2 Feb. 1979	269	
Sweden[33]		Accession: 1 Jun. 1995	193	In force: 30 Apr. 2004
Switzerland		In force: 6 Sep. 1978	264	In force: 1 Feb. 2005
Syrian Arab Republic		In force: 18 May 1992	407	
Tajikistan		In force: 14 Dec. 2004	639	In force: 14 Dec. 2004
Thailand		In force: 16 May 1974	241	In force: 17 Nov. 2017
Timor-Leste	*Signed: 6 Oct. 2009*	*Signed: 6 Oct. 2009*		*Signed: 6 Oct. 2009*
Togo	Amended: 8 Oct. 2015	In force: 18 Jul. 2012	840	In force: 18 Jul. 2012
Tonga	Amended: 3 Apr. 2018	In force: 18 Nov. 1993	426	
Trinidad and Tobago[2]	X	In force: 4 Nov. 1992	414	
Tunisia		In force: 13 Mar. 1990	381	Signed: 24 May 2005
Türkiye		In force: 1 Sep. 1981	295	In force: 17 Jul. 2001
Turkmenistan		In force: 3 Jan. 2006	673	In force: 3 Jan. 2006
Tuvalu	X	In force: 15 Mar. 1991	391	
Uganda	Amended: 24 Jun. 2009	In force: 14 Feb. 2006	674	In force: 14 Feb. 2006
Ukraine		In force: 22 Jan. 1998	550	In force: 24 Jan. 2006
United Arab Emirates		In force: 9 Oct. 2003	622	In force: 20 Dec. 2010
United Kingdom	Signed: 6 Jan. 1993	In force: 14 Dec. 1972[34] Signed: 6 Jan. 1993[15] In force: 31 Dec. 2020[35]	175 951*	In force: 31 Dec. 2020[35]
United Republic of Tanzania	Amended: 10 Jun. 2009	In force: 7 Feb. 2005	643	In force: 7 Feb. 2005
United States of America	Amended: 3 Jul. 2018	In force: 9 Dec. 1980 In force: 6 Apr. 1989[15]	288* 366	In force: 6 Jan. 2009
Uruguay[2]		In force: 17 Sep. 1976	157	In force: 30 Apr. 2004
Uzbekistan		In force: 8 Oct. 1994	508	In force: 21 Dec. 1998

State [a]	Small quantities protocols [b]	Safeguards agreements [c]	INFCIRC	Additional protocols
Vanuatu	In force: 21 May 2013	In force: 21 May 2013	852	In force: 21 May 2013
Venezuela, Bolivarian Republic of [2]		In force: 11 Mar. 1982	300	
Viet Nam		In force: 23 Feb. 1990	376	In force: 17 Sep. 2012
Yemen	X	In force: 14 Aug. 2002	614	
Zambia	X	In force: 22 Sep. 1994	456	Signed: 13 May 2009
Zimbabwe	Amended: 31 Aug. 2011	In force: 26 Jun. 1995	483	In force: 21 Sep. 2021

Key

Bold States not party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) whose safeguards agreements are of INFCIRC/66-type.

Italics States Parties to the NPT that have not yet brought into force comprehensive safeguards agreements (CSAs) pursuant to Article III of the NPT.

* Voluntary offer safeguards agreement with NPT nuclear-weapon States.

X 'X' in the 'small quantities protocols' column indicates that the State has an operative small quantities protocol (SQP). 'Amended' indicates that the operative SQP is based on the revised SQP standardized text.

NB: This table does not aim at listing all safeguards agreements that the Agency has concluded. Not included are agreements under which the application of safeguards has been suspended upon the entry into force of a CSA. Unless otherwise indicated, the safeguards agreements referred to are CSAs concluded pursuant to the NPT.

[a] An entry in this column does not imply the expression of any opinion whatsoever on the part of the Agency concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

[b] Provided that they meet certain eligibility criteria (including that the quantities of nuclear material do not exceed the limits set out in paragraph 37 of INFCIRC/153 (Corrected)), countries have the option to conclude an SQP to their CSAs that holds in abeyance the implementation of most of the detailed provisions set out in Part II of the CSAs as long as eligibility criteria continue to apply. This column contains countries whose CSA with an SQP based on the original standard text has been approved by the Board of Governors and for which, as far as the Secretariat is aware, these eligibility criteria continue to apply. For those States that have accepted the revised standard SQP text (approved by the Board of Governors on 20 September 2005) the current status is reflected.

[c] The Agency also applies safeguards for Taiwan, China, under two agreements, which entered into force on 13 October 1969 (reproduced in INFCIRC/133) and 6 December 1971 (reproduced in INFCIRC/158), respectively.

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[1] *Sui generis comprehensive safeguards agreement. On 28 November 2002, upon approval by the Board of Governors, an exchange of letters entered into force confirming that the safeguards agreement satisfies the requirement of Article III of the NPT.*

[2] Safeguards agreement is pursuant to both the Treaty of Tlatelolco and the NPT.

[3] Date refers to the safeguards agreement concluded between Argentina, Brazil, ABACC and the Agency. On 18 March 1997, upon approval by the Board of Governors, an exchange of letters entered into force between Argentina and the Agency confirming that the safeguards agreement satisfies the requirements of Article 13 of the Treaty of Tlatelolco and Article III of the NPT to conclude a safeguards agreement with the Agency.

[4] The application of safeguards for Austria under the NPT bilateral safeguards agreement (reproduced in INFCIRC/156), in force since 23 July 1972, was suspended on 31 July 1996, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Austria had acceded, entered into force for Austria.

[5] Date refers to a safeguards agreement pursuant to Article III of the NPT. Upon approval by the Board of Governors, an exchange of letters entered into force (for Saint Lucia on 12 June 1996 and for Belize, Dominica, Saint Kitts and Nevis and Saint Vincent and the Grenadines on 18 March 1997) confirming that the safeguards agreement satisfies the requirement of Article 13 of the Treaty of Tlatelolco.

[6] Date refers to the safeguards agreement concluded between Argentina, Brazil, ABACC and the Agency. On 10 June 1997, upon approval by the Board of Governors, an exchange of letters entered into force between Brazil and the Agency confirming that the safeguards agreement satisfies the requirement of Article 13 of the Treaty of Tlatelolco. On 20 September 1999, upon approval by the Board of Governors, an exchange of letters entered into force confirming that the safeguards agreement also satisfies the requirement of Article III of the NPT.

[7] The application of safeguards for Bulgaria under the NPT bilateral safeguards agreement (reproduced in INFCIRC/178), in force since 29 February 1972, was suspended on 1 May 2009, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Bulgaria had acceded, entered into force for Bulgaria.

[8] Date refers to a safeguards agreement pursuant to Article 13 of the Treaty of Tlatelolco. Upon approval by the Board of Governors, an exchange of letters entered into force (for Chile on 9 September 1996; for Colombia on 13 June 2001; for Panama on 20 November 2003) confirming that the safeguards agreement satisfies the requirement of Article III of the NPT.

[9] The application of safeguards for Croatia under the NPT bilateral safeguards agreement (reproduced in INFCIRC/463), in force since 19 January 1995, was suspended on 1 April 2017, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Croatia had acceded, entered into force for Croatia.

[10] The application of safeguards for Cyprus under the NPT bilateral safeguards agreement (reproduced in INFCIRC/189), in force since 26 January 1973, was suspended on 1 May 2008, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Cyprus had acceded, entered into force for Cyprus.

[11] The application of safeguards for the Czech Republic under the NPT bilateral safeguards agreement (reproduced in INFCIRC/541), in force since 11 September 1997, was suspended on 1 October 2009, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which the Czech Republic had acceded, entered into force for the Czech Republic.

[12] The application of safeguards for Denmark under the NPT bilateral safeguards agreement (reproduced in INFCIRC/176), in force since 1 March 1972, was suspended on 21 February 1977, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193) entered into force for Denmark. Since 21 February 1977, INFCIRC/193 also applies to the Faroe Islands. Upon Greenland's secession from Euratom as of 31 January 1985, INFCIRC/176 re-entered into force for Greenland. The Additional Protocol for Greenland entered into force on 22 March 2013 (reproduced in INFCIRC/176/Add.1).

[13] The application of safeguards for Estonia under the NPT bilateral safeguards agreement (reproduced in INFCIRC/547), in force since 24 November 1997, was suspended on 1 December 2005, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Estonia had acceded, entered into force for Estonia.

[14] The application of safeguards for Finland under the NPT bilateral safeguards agreement (reproduced in INFCIRC/155), in force since 9 February 1972, was suspended on 1 October 1995, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Finland had acceded, entered into force for Finland.

[15] The safeguards agreement is in connection with Additional Protocol I to the Treaty of Tlatelolco.

[16] The NPT safeguards agreement of 7 March 1972 concluded with the German Democratic Republic (reproduced in INFCIRC/181) is no longer in force with effect from 3 October 1990, on which date the German Democratic Republic acceded to the Federal Republic of Germany.

[17] The application of safeguards for Greece under the NPT bilateral safeguards agreement (reproduced in INFCIRC/166), in force since 1 March 1972, was suspended on 17 December 1981, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Greece had acceded, entered into force for Greece.

[18] The application of safeguards for Hungary under the NPT bilateral safeguards agreement (reproduced in INFCIRC/174), in force since 30 March 1972, was suspended on 1 July 2007, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Hungary had acceded, entered into force for Hungary.

[19] The application of safeguards for India under the safeguards agreement between the Agency, Canada and India (reproduced in INFCIRC/211), in force since 30 September 1971, was suspended as of 20 March 2015. The application of safeguards for India under the safeguards agreements between the Agency and India reproduced in the following INFCIRCs was suspended as of 30 June 2016: INFCIRC/260, in force since 17 November 1977; INFCIRC/360, in force since 27 September 1988; INFCIRC/374, in force since 11 October 1989; and INFCIRC/433, in force since 1 March 1994. Items subject to safeguards under the aforementioned safeguards agreements are subject to safeguards under the safeguards agreement between India and the Agency (reproduced in INFCIRC/754), which entered into force on 11 May 2009.

[20] On 16 January 2016, as notified in its letter to the Director General of 7 January 2016, Iran began to provisionally apply its additional protocol in accordance with Article 17(b) of the Additional Protocol, pending its entry into force. The additional protocol, which was provisionally applied by Iran as of 16 January 2016, has not been applied since 23 February 2021.

[21] The application of safeguards for Latvia under the NPT bilateral safeguards agreement (reproduced in INFCIRC/434), in force since 21 December 1993, was suspended on 1 October 2008, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Latvia had acceded, entered into force for Latvia.

[22] The application of safeguards for Lithuania under the NPT bilateral safeguards agreement (reproduced in INFCIRC/413), in force since 15 October 1992, was suspended on 1 January 2008, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Lithuania had acceded, entered into force for Lithuania.

[23] The application of safeguards for Malta under the NPT bilateral safeguards agreement (reproduced in INFCIRC/387), in force since 13 November 1990, was suspended on 1 July 2007, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Malta had acceded, entered into force for Malta.

[24] The safeguards agreement was concluded pursuant to both the Treaty of Tlatelolco and the NPT. The application of safeguards under an earlier safeguards agreement pursuant to the Treaty of Tlatelolco, which entered into force on 6 September 1968 (reproduced in INFCIRC/118), was suspended as of 14 September 1973.

[25] Whereas the NPT safeguards agreement and SQP with New Zealand (reproduced in INFCIRC/185) also apply to Cook Islands and Niue, the additional protocol thereto (reproduced in INFCIRC/185/Add.1) does not apply to those territories. Amendments to the SQP entered into force only for New Zealand on 24 February 2014 (reproduced in INFCIRC/185/Mod.1).

[26] The application of safeguards for Poland under the NPT bilateral safeguards agreement (reproduced in INFCIRC/179), in force since 11 October 1972, was suspended on 1 March 2007, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Poland had acceded, entered into force for Poland.

[27] The application of safeguards for Portugal under the NPT bilateral safeguards agreement (reproduced in INFCIRC/272), in force since 14 June 1979, was suspended on 1 July 1986, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Portugal had acceded, entered into force for Portugal.

[28] The application of safeguards for Romania under the NPT bilateral safeguards agreement (reproduced in INFCIRC/180), in force since 27 October 1972, was suspended on 1 May 2010, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Romania had acceded, entered into force for Romania.

[29] The NPT safeguards agreement concluded with the Socialist Federal Republic of Yugoslavia (reproduced in INFCIRC/204), which entered into force on 28 December 1973, continues to be applied for Serbia to the extent relevant to the territory of Serbia.

[30] The application of safeguards for Slovakia under the NPT bilateral safeguards agreement with the Czechoslovak Socialist Republic (reproduced in INFCIRC/173), in force since 3 March 1972, was suspended on 1 December 2005, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Slovakia had acceded, entered into force for Slovakia.

[31] The application of safeguards for Slovenia under the NPT bilateral safeguards agreement (reproduced in INFCIRC/538), in force since 1 August 1997, was suspended on 1 September 2006, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Slovenia had acceded, entered into force for Slovenia.

[32] The designation employed does not imply the expression of any opinion whatsoever concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

[33] The application of safeguards for Sweden under the NPT bilateral safeguards agreement (reproduced in INFCIRC/234), in force since 14 April 1975, was suspended on 1 June 1995, on which date the agreement of 5 April 1973 between the non-nuclear-weapon States of Euratom, Euratom and the Agency (reproduced in INFCIRC/193), to which Sweden had acceded, entered into force for Sweden.

[34] Date refers to the INFCIRC/66-type safeguards agreement, concluded between the United Kingdom and the Agency, which remains in force.

[35] The voluntary offer safeguards agreement between the United Kingdom, Euratom and the Agency (reproduced in INFCIRC/263) and the additional protocol thereto (reproduced in INFCIRC/263/Add.1) terminated on 31 December 2020 at 23:00 GMT.

Table A7. Participation in multilateral treaties for which the Director General is the depositary (status as of 31 December 2021)

	State/Organization[a]	P&I	ENC	AC	CNS	JC	CPPNM	A/CPPNM	VC	PVC	CSC	JP
*	Afghanistan						X					
*	Albania	X	X	X	X	X	X	X				
*	Algeria		X	X			X	X				
	Andorra						X					
*	Angola		X		X		X	X				
*	Antigua and Barbuda						X	X				
*	Argentina	X	X	X	X	X	X	X	X	X	X	
*	Armenia		X	X	X	X	X	X	X			
*	Australia	X	X	X	X	X	X	X				
*	Austria		X	X	X	X	X	X				
*	Azerbaijan						X	X				
*	Bahamas						X					
*	Bahrain		X		X		X	X				
*	Bangladesh		X	X	X		X	X				
*	Barbados											
*	Belarus	X	X	X	X	X	X		X	X		
*	Belgium	X	X	X	X	X	X	X				
*	Belize											
*	Benin	X	X	X	X	X	X	X	X	X	X	X
	Bhutan											
*	Bolivia, Plurinational State of	X	X	X	X	X	X	X	X			
*	Bosnia and Herzegovina	X	X	X	X	X	X	X	X	X		
*	Botswana		X	X		X	X	X				
*	Brazil	X	X	X	X	X	X		X			
*	Brunei Darussalam	X										
*	Bulgaria	X	X	X	X	X	X	X	X			X

	State/Organization[a]	P&I	ENC	AC	CNS	JC	CPPNM	A/CPPNM	VC	PVC	CSC	JP
*	Burkina Faso		X	X			X	X				
*	Burundi											
	Cabo Verde						X					
*	Cambodia		X		X		X					
*	Cameroon	X	X	X			X	X	X			X
*	Canada	X	X	X	X	X	X	X			X	
*	Central African Republic						X					
*	Chad						X	X				
*	Chile	X	X	X	X	X	X	X	X			X
*	China	X	X	X	X	X	X	X				
*	Colombia	X	X	X			X	X				
*	Comoros						X	X				
*	Congo	X	X		X	X	X					
*	Costa Rica		X	X			X	X				
*	Côte d'Ivoire	X	X	X			X	X				
*	Croatia	X	X	X	X	X	X	X	X			X
*	Cuba	X	X	X	X	X	X	X	X			
*	Cyprus	X	X	X	X	X	X	X				
*	Czech Republic	X	X	X	X	X	X	X	X			X
	Dem. People's Rep. of Korea											
*	Dem. Rep. of the Congo	X					X					
*	Denmark	X	X	X	X	X	X	X				X
*	Djibouti						X	X				
*	Dominica						X					
*	Dominican Republic		X				X	X				
*	Ecuador	X	X	X			X	X				
*	Egypt	X	X	X					X			X
*	El Salvador		X	X			X	X				

	State/Organization[a]	P&I	ENC	AC	CNS	JC	CPPNM	A/CPPNM	VC	PVC	CSC	JP
	Equatorial Guinea						X					
*	Eritrea	X	X	X		X	X	X				
*	Estonia	X	X	X	X	X	X	X	X			X
*	Eswatini						X	X				
*	Ethiopia											
*	Fiji						X	X				
*	Finland	X	X	X	X	X	X	X				X
*	France		X	X	X	X	X	X				X
*	Gabon		X	X		X	X	X				
	Gambia											
*	Georgia	X	X	X		X	X	X				
*	Germany	X	X	X	X	X	X	X				X
*	Ghana	X	X	X	X	X	X	X	X	X	X	X
*	Greece	X	X	X	X	X	X	X				X
*	Grenada						X					
*	Guatemala		X	X			X					
	Guinea						X					
	Guinea-Bissau						X					
*	Guyana						X					
*	Haiti											
*	Holy See	X										
*	Honduras						X					
*	Hungary	X	X	X	X	X	X	X	X			X
*	Iceland	X	X	X	X	X	X	X				
*	India	X	X	X	X		X	X			X	
*	Indonesia	X	X	X	X	X	X	X				
*	Iran, Islamic Republic of	X	X	X								
*	Iraq	X	X	X			X					

	State/Organization[a]	P&I	ENC	AC	CNS	JC	CPPNM	A/CPPNM	VC	PVC	CSC	JP
*	Ireland	X	X	X	X	X	X	X				
*	Israel		X	X			X	X				
*	Italy	X	X	X	X	X	X	X				X
*	Jamaica	X					X	X				
*	Japan	X	X	X	X	X	X	X			X	
*	Jordan	X	X	X	X	X	X	X	X	X		
*	Kazakhstan	X	X	X	X	X	X	X	X	X		
*	Kenya						X	X				
	Kiribati											
*	Korea, Republic of	X	X	X	X	X	X	X				
*	Kuwait	X	X	X	X		X	X				
*	Kyrgyzstan					X	X	X				
*	Lao People's Dem. Rep.		X	X			X					
*	Latvia	X	X	X	X	X	X	X	X	X		X
*	Lebanon		X	X	X		X		X			
*	Lesotho	X	X	X		X	X	X				
*	Liberia											
*	Libya		X	X	X		X	X				
*	Liechtenstein		X	X			X	X				
*	Lithuania	X	X	X	X	X	X	X	X			X
*	Luxembourg	X	X	X	X	X	X	X				
*	Madagascar		X	X	X	X	X	X				
*	Malawi						X					
*	Malaysia		X	X								
	Maldives											
*	Mali		X	X	X		X	X				
*	Malta				X	X	X	X				
*	Marshall Islands						X	X				

	State/Organization[a]	P&I	ENC	AC	CNS	JC	CPPNM	A/CPPNM	VC	PVC	CSC	JP
*	Mauritania		X	X		X	X	X				
*	Mauritius	X	X	X		X			X			
*	Mexico	X	X	X	X	X	X	X	X			
	Micronesia, Federated States of											
*	Monaco		X	X			X	X				
*	Mongolia	X	X	X			X					
*	Montenegro	X	X	X	X	X	X	X	X	X	X	X
*	Morocco	X	X	X	X	X	X	X		X	X	
*	Mozambique	X	X	X			X					
*	Myanmar		X		X		X	X				
*	Namibia		X	X			X	X				
	Nauru						X	X				
*	Nepal											
*	Netherlands	X	X	X	X	X	X	X				X
*	New Zealand	X	X	X			X	X				
*	Nicaragua	X	X	X			X	X				
*	Niger	X	X	X	X	X	X	X	X	X		
*	Nigeria	X	X	X	X	X	X	X	X			
	Niue						X					
*	North Macedonia		X	X	X	X	X	X	X			
*	Norway	X	X	X	X	X	X	X				X
*	Oman	X	X	X	X	X	X					
*	Pakistan	X	X	X	X		X	X				
*	Palau	X					X					
	Palestine						X[b]	X[b]				
*	Panama		X	X			X	X				
*	Papua New Guinea											
*	Paraguay	X	X	X	X	X	X	X				

	State/Organization[a]	P&I	ENC	AC	CNS	JC	CPPNM	A/CPPNM	VC	PVC	CSC	JP
*	Peru		X	X	X	X	X	X	X			
*	Philippines	X	X	X			X	X	X			
*	Poland	X	X	X	X	X	X	X	X	X		X
*	Portugal	X	X	X	X	X	X	X				
*	Qatar		X	X	X		X	X				
*	Republic of Moldova	X	X	X	X	X	X	X	X			
*	Romania	X	X	X	X	X	X	X	X	X	X	X
*	Russian Federation	X	X	X	X	X	X	X	X			
*	Rwanda		X	X		X	X	X	X			
	Saint Kitts and Nevis						X	X				
*	Saint Lucia						X	X				
*	Saint Vincent and the Grenadines		X	X					X			X
*	Samoa											
*	San Marino						X	X				
	São Tomé and Príncipe											
*	Saudi Arabia		X	X	X	X	X	X	X	X		
*	Senegal	X	X	X	X	X	X	X	X			
*	Serbia	X	X	X	X	X	X	X	X			
*	Seychelles						X	X				
*	Sierra Leone											
*	Singapore	X	X	X	X		X	X				
*	Slovakia	X	X	X	X	X	X	X	X			X
*	Slovenia	X	X	X	X	X	X	X				X
	Solomon Islands											
	Somalia											
*	South Africa	X	X	X	X	X	X					
	South Sudan											
*	Spain	X	X	X	X	X	X	X				

	State/Organization[a]	P&I	ENC	AC	CNS	JC	CPPNM	A/CPPNM	VC	PVC	CSC	JP
*	Sri Lanka		X	X	X							
*	Sudan						X					
	Suriname											
*	Sweden	X	X	X	X	X	X	X				X
*	Switzerland	X	X	X	X	X	X	X				
*	Syrian Arab Republic	X	X	X	X		X	X				
*	Tajikistan	X	X	X		X	X	X				
*	Thailand	X	X	X	X	X	X	X				
	Timor Leste											
*	Togo						X					
	Tonga						X					
*	Trinidad and Tobago						X		X			
*	Tunisia	X	X	X	X		X	X				
*	Türkiye	X	X	X	X		X	X				X
*	Turkmenistan						X	X				
	Tuvalu											
*	Uganda						X					
*	Ukraine	X	X	X	X	X	X	X	X			X
*	United Arab Emirates		X	X	X	X	X	X		X	X	X
*	United Kingdom	X	X	X	X	X	X	X				
*	United Republic of Tanzania		X	X			X					
*	United States of America		X	X	X	X	X	X			X	
*	Uruguay		X	X	X	X	X	X	X			X
*	Uzbekistan					X	X	X				
*	Vanuatu											
*	Venezuela, Bolivarian Republic of		X									
*	Viet Nam	X	X	X	X	X	X	X				
*	Yemen						X					

	State/Organization[a]	P&I	ENC	AC	CNS	JC	CPPNM	A/CPPNM	VC	PVC	CSC	JP
*	Zambia						X					
*	Zimbabwe		X	X		X	X					
	Euratom		X	X	X	X	X	X				
	FAO		X	X								
	WHO		X	X								
	WMO		X	X								

P&I	Agreement on the Privileges and Immunities of the IAEA
ENC	Convention on Early Notification of a Nuclear Accident
AC	Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency
CNS	Convention on Nuclear Safety
JC	Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management
CPPNM	Convention on the Physical Protection of Nuclear Material
A/CPPNM	Amendment to the Convention on the Physical Protection of Nuclear Material
VC	Vienna Convention on Civil Liability for Nuclear Damage
PVC	Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage
CSC	Convention on Supplementary Compensation for Nuclear Damage
JP	Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention
*	Agency Member State
X	Party

[a] An entry in this column does not imply the expression of any opinion whatsoever on the part of the Agency concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

[b] Acceded as State of Palestine.

Table A8. Member States that have concluded a Revised Supplementary Agreement (RSA) Concerning the Provision of Technical Assistance by the Agency (status as of 31 December 2021)[a]

Afghanistan
Albania
Algeria
Angola
Antigua and Barbuda
Argentina
Armenia
Azerbaijan
Bahrain
Bangladesh
Belarus
Belize
Benin
Bolivia, Plurinational State of
Bosnia and Herzegovina
Botswana
Brazil
Brunei Darussalam
Bulgaria
Burkina Faso
Burundi
Cambodia
Cameroon
Central African Republic
Chad
Chile
China
Colombia
Congo
Costa Rica
Côte d'Ivoire
Croatia
Cuba
Cyprus
Czech Republic
Democratic Republic of the Congo
Djibouti
Dominica
Dominican Republic
Ecuador
Egypt
El Salvador
Eritrea
Estonia
Eswatini
Ethiopia
Fiji
Gabon
Georgia
Ghana
Greece
Guatemala
Guyana
Haiti
Honduras
Hungary
Iceland
Indonesia
Iran, Islamic Republic of
Iraq
Ireland
Israel
Jamaica
Jordan
Kazakhstan
Kenya
Korea, Republic of
Kuwait
Kyrgyzstan
Lao People's Democratic Republic
Latvia
Lebanon
Lesotho
Liberia
Libya
Lithuania
Madagascar
Malawi
Malaysia
Mali
Malta
Marshall Islands
Mauritania
Mauritius
Mexico
Mongolia
Montenegro
Morocco
Mozambique
Myanmar
Namibia
Nepal
Nicaragua
Niger
Nigeria
North Macedonia
Oman
Pakistan
Palau
Panama
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Republic of Moldova
Romania
Rwanda
Saint Lucia
Saint Vincent and the Grenadines
Saudi Arabia
Senegal
Serbia
Seychelles
Sierra Leone
Singapore
Slovakia
Slovenia
South Africa
Spain
Sri Lanka
Sudan
Syrian Arab Republic
Tajikistan
Thailand
Togo
Trinidad and Tobago
Tunisia
Türkiye
Turkmenistan
Uganda
Ukraine
United Arab Emirates
United Republic of Tanzania
Uruguay
Uzbekistan
Vanuatu
Venezuela, Bolivarian Republic of
Viet Nam
Zambia
Zimbabwe

[a] In 2021, Brunei Darussalam concluded an RSA with the Agency. By the end of the year, there were 142 States party to an RSA.

Table A9. Acceptance of Amendment to Article VI of the Agency's Statute (status as of 31 December 2021)[a]

Afghanistan
Albania
Algeria
Argentina
Austria
Belarus
Bosnia and Herzegovina
Brazil
Bulgaria
Canada
Colombia
Croatia
Cyprus
Czech Republic
Denmark
El Salvador
Estonia
Ethiopia
Finland
France
Germany
Greece
Holy See
Hungary
Iceland
Ireland
Israel
Italy
Japan
Kazakhstan
Korea, Republic of
Latvia
Libya
Liechtenstein
Lithuania
Luxembourg
Malta
Mexico
Monaco
Morocco
Myanmar
Netherlands
Norway
Pakistan
Panama
Peru
Poland
Portugal
Republic of Moldova
Romania
San Marino
Slovakia
Slovenia
South Africa
Spain
Sweden
Switzerland
Tunisia
Türkiye
Ukraine
United Kingdom
Uruguay

[a] In 2021, no State accepted the Amendment to Article VI of the Agency's Statute. By the end of the year, there were 62 States.

Table A10. Acceptance of Amendment to Article XIV.A of the Agency's Statute (status as of 31 December 2021)[a]

Albania	Greece	Norway
Algeria	Holy See	Pakistan
Argentina	Hungary	Peru
Australia	Iceland	Poland
Austria	Iran, Islamic Republic of	Portugal
Belarus	Ireland	Republic of Moldova
Bosnia and Herzegovina	Italy	Romania
Brazil	Japan	San Marino
Bulgaria	Kazakhstan	Seychelles
Canada	Kenya	Slovakia
Colombia	Korea, Republic of	Slovenia
Croatia	Latvia	South Africa
Cyprus	Liechtenstein	Spain
Czech Republic	Lithuania	Sweden
Denmark	Luxembourg	Switzerland
Ecuador	Malta	Syrian Arab Republic
Estonia	Mexico	Tunisia
Finland	Monaco	Türkiye
France	Myanmar	Ukraine
Germany	Netherlands	United Kingdom

[a] In 2021, no State accepted the Amendment to Article XIV.A of the Agency's Statute. By the end of the year, there were 60 States.

Table A11. Multilateral treaties negotiated and adopted under the auspices of the Agency and/or for which the Director General is the depositary (status and relevant developments)

Agreement on the Privileges and Immunities of the IAEA (reproduced in INFCIRC/9/Rev.2). In 2021, the status remained unchanged with 91 Parties.

Convention on Early Notification of a Nuclear Accident (reproduced in INFCIRC/335). Entered into force on 27 October 1986. In 2021, there were 4 new Parties to the Convention. By the end of the year, there were 131 Parties.

Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (reproduced in INFCIRC/336). Entered into force on 26 February 1987. In 2021, there were 2 new Parties to the Convention. By the end of the year, there were 124 Parties.

Convention on Nuclear Safety (reproduced in INFCIRC/449). Entered into force on 24 October 1996. In 2021, there were 2 new Parties to the Convention. By the end of the year, there were 91 Parties.

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (reproduced in INFCIRC/546). Entered into force on 18 June 2001. In 2021, there were 3 new Parties and 1 new Contracting State to the Convention. By the end of the year, there were 86 Parties and 1 Contracting State.

Convention on the Physical Protection of Nuclear Material (reproduced in INFCIRC/274/Rev.1). Entered into force on 8 February 1987. In 2021, there were 2 new Parties to the Convention. By the end of the year, there were 164 Parties.

Amendment to the Convention on the Physical Protection of Nuclear Material. Entered into force on 8 May 2016. In 2021, there were 2 new Parties to the Amendment. By the end of the year, there were 127 Parties.

Vienna Convention on Civil Liability for Nuclear Damage (reproduced in INFCIRC/500). Entered into force on 12 November 1977. In 2021, the status of the Convention remained unchanged with 43 Parties.

Optional Protocol Concerning the Compulsory Settlement of Disputes (reproduced in INFCIRC/500/Add.3). Entered into force on 13 May 1999. In 2021, the status of the Protocol remained unchanged with 2 Parties.

Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage (reproduced in INFCIRC/566). Entered into force on 4 October 2003. In 2021, the status of the Protocol remained unchanged with 15 Parties.

Convention on Supplementary Compensation for Nuclear Damage (reproduced in INFCIRC/567). Entered into force on 15 April 2015. In 2021, the status of the Convention remained unchanged with 11 Parties.

Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention (reproduced in INFCIRC/402). Entered into force on 27 April 1992. In 2021, the status of the Protocol remained unchanged with 31 Parties.

Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (RCA), 2017 (reproduced in INFCIRC/919). Entered into force on 11 June 2017. In 2021, the status of the Agreement remained unchanged with 19 Parties.

African Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (AFRA) (reproduced in INFCIRC/935). Entered into force on 4 April 2020. In 2021, there were 2 new Parties to the Agreement. By the end of the year, there were 13 Parties.

Agreement to further extend the Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean (ARCAL) (Second Extension) (reproduced in INFCIRC/582/Add. 5). Entered into force on 5 September 2020. In 2021, there were 5 new Parties to the Agreement. By the end of the year, there were 20 Parties.

Co-operative Agreement for Arab States in Asia for Research, Development and Training Related to Nuclear Science and Technology (the 2017 ARASIA) (reproduced in INFCIRC/929). Entered into force on 28 July 2020. In 2021, there was 1 new Party to the Agreement. By the end of the year, there were 6 Parties.

Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project (reproduced in INFCIRC/702). Entered into force on 24 October 2007. In 2021, the status of the Agreement remained unchanged with 7 Parties.

Agreement on the Privileges and Immunities of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project (reproduced in INFCIRC/703). Entered into force on 24 October 2007. In 2021, the status of the Agreement remained unchanged with 6 Parties.

Table A12. Nuclear power reactors in operation and under construction in the world (status as of 31 December 2021)[a]

Country	Reactors in operation		Reactors under construction		Nuclear electricity supplied in 2021		Total operating experience through 2021	
	No. of units	Total MW(e)	No. of units	Total MW(e)	TW·h	% of total	Years	Months
Argentina	3	1 641	1	25	10.2	7.2	94	2
Armenia	1	448			1.9	25.3	47	8
Bangladesh			2	2 160	NA	NA		
Belarus	1	1 110	1	1 110	5.4	14.1	1	2
Belgium	7	5 942			48.0	50.8	317	7
Brazil	2	1 884	1	1 340	13.9	2.4	61	3
Bulgaria	2	2 006			15.8	34.6	171	3
Canada	19	13 624			86.8	14.3	807	6
China	53	50 034	16	15 967	383.2	5.0	470	0
Czech Republic	6	3 934			29.0	36.6	182	10
Finland	4	2 794	1	1 600	22.6	32.8	171	4
France	56	61 370	1	1 630	363.4	69.0	2 393	0
Germany	3	4 055			65.4	11.9	830	11
Hungary	4	1 916			15.1	46.8	146	2
India	22	6 795	8	6 028	39.8	3.2	554	9
Iran, Islamic Republic of	1	915	1	974	3.2	1.0	10	4
Japan	33	31 679	2	2 653	61.3	7.2	1 965	6
Korea, Republic of	24	23 091	4	5 360	150.5	28.0	620	2
Mexico	2	1 552			11.6	5.3	59	11
Netherlands	1	482			3.6	3.1	77	0
Pakistan	5	2 242	1	1 014	15.8	10.6	92	11
Romania	2	1 300			10.4	18.5	39	11
Russian Federation	37	27 727	4	3 759	208.4	20.0	1 410	7
Slovakia	4	1 868	2	880	14.6	52.3	180	7
Slovenia	1	688			5.4	36.9	40	3

Country	Reactors in operation		Reactors under construction		Nuclear electricity supplied in 2021		Total operating experience through 2021	
	No. of units	Total MW(e)	No. of units	Total MW(e)	TW·h	% of total	Years	Months
South Africa	2	1 854			12.2	6.0	74	3
Spain	7	7 121			54.2	20.8	357	1
Sweden	6	6 882			51.4	30.8	480	0
Switzerland	4	2 960			18.6	28.8	232	11
Türkiye			3	3 342	NA	NA	NA	NA
Ukraine	15	13 107	2	2 070	81.1	55.0	548	6
United Arab Emirates	2	2 762	2	2 690	10.1	1.3	1	9
United Kingdom	12	7 343	2	3 260	41.8	18.8	1 648	6
United States of America	93	95 523	2	2 234	771.6	19.6	4 694	4
Total [b, c]	**437**	**389 508**	**56**	**58 096**	**2 653.1**	**NA**	**19 170**	**9**

Note: NA — Not applicable.

[a] Source: Agency's Power Reactor Information System (PRIS) (www.iaea.org/pris) as of 31 May 2022.

[b] The total figures include the following data from Taiwan, China: 3 units, 2 859 MW(e) in operation and 26.8 TWh of electricity supplied, accounting for 10.8% of total electricity mix.

[c] The total operating experience also includes shutdown plants in Italy (80 years, 8 months), Kazakhstan (25 years, 10 months) and Lithuania (43 years, 6 months), and shutdown and operational plants in Taiwan, China (236 years, 8 months).

Table A13. Member State participation in selected Agency activities in 2021

Member State	No. of research contracts and agreements	No. of Collaborating Centres	Services provided to Member States		
			ALMERA[a]	Dosimetry audits for radiotherapy	Plant irradiation services
Afghanistan					
Albania	2			2	
Algeria	8				
Angola	1			2	
Antigua and Barbuda					
Argentina	46	1	2		
Armenia	2			2	
Australia	39	1	3		
Austria	10		4		
Azerbaijan	3				
Bahamas	1			2	
Bahrain					
Bangladesh	16			16	
Barbados				1	
Belarus	6		1	21	
Belgium	20		2		
Belize					
Benin	1				
Bolivia, Plurinational State of	1			10	
Bosnia and Herzegovina	2		3	8	1
Botswana	1				
Brazil	55	3	4		
Brunei Darussalam					
Bulgaria	6		2	13	
Burkina Faso	8	1			1

Member State	No. of research contracts and agreements	No. of Collaborating Centres	Services provided to Member States		
			ALMERA[a]	Dosimetry audits for radiotherapy	Plant irradiation services
Burundi					
Cambodia					
Cameroon	7			2	
Canada	39	1	3		
Central African Republic					1
Chad	1				
Chile	13		1		
China	95	5	3	14	
Colombia	5			1	
Congo					
Costa Rica	10	1	1		
Côte d'Ivoire	1				
Croatia	14		2	14	2
Cuba	14		3		
Cyprus			1	3	
Czech Republic	9		1		
Dem. Rep. of the Congo	1				
Denmark	3		1		
Djibouti					
Dominica					
Dominican Republic					
Ecuador	7		1		
Egypt	22	2	1		
El Salvador				10	
Eritrea					1
Estonia	4		1		

Member State	No. of research contracts and agreements	No. of Collaborating Centres	Services provided to Member States		
			ALMERA[a]	Dosimetry audits for radiotherapy	Plant irradiation services
Eswatini					
Ethiopia	10		1	3	
Fiji					
Finland	13		1		
France	58	4	5		
Gabon					
Georgia				3	
Germany	42		4		4
Ghana	16			2	
Greece	18		6		1
Grenada					
Guatemala	3			8	
Guyana				1	
Haiti					
Holy See					
Honduras					1
Hungary	21	2	3	14	1
Iceland			1		
India	71	1	3	43	
Indonesia	31	2	1	15	
Iran, Islamic Republic of	18		3		
Iraq			1		1
Ireland	3		1		
Israel	10		2	16	
Italy	37	3	8		
Jamaica	6		1		

Member State	No. of research contracts and agreements	No. of Collaborating Centres	Services provided to Member States		
			ALMERA[a]	Dosimetry audits for radiotherapy	Plant irradiation services
Japan	38	3	5		
Jordan	4		1	3	
Kazakhstan	1		1	6	
Kenya	16		1	7	1
Korea, Republic of	31	2	2		
Kuwait	6	1	1	3	
Kyrgyzstan	2				1
Lao People's Dem. Rep.					
Latvia			1		
Lebanon	6		1	10	
Lesotho					
Liberia					
Libya					
Liechtenstein					
Lithuania	8		3	8	
Luxembourg	1		1		
Madagascar	4		1		
Malawi	1				
Malaysia	25	1	1	22	
Mali	1				
Malta					
Marshall Islands					
Mauritania				3	
Mauritius	4				
Mexico	32	2	3	45	
Monaco					
Mongolia	3		1	3	

Member State	No. of research contracts and agreements	No. of Collaborating Centres	Services provided to Member States		
			ALMERA[a]	Dosimetry audits for radiotherapy	Plant irradiation services
Montenegro	2		1	3	
Morocco	23	2	1	21	
Mozambique					
Myanmar	4		1		
Namibia	4				3
Nepal	1				
Netherlands	11	1	4		1
New Zealand	6		1		
Nicaragua	1			1	
Niger				1	
Nigeria	5		1	6	2
North Macedonia	6		1	3	1
Norway	4	1	2		
Oman				5	
Pakistan	39	1	1		
Palau					
Panama			1		
Papua New Guinea	1				
Paraguay					
Peru	8	1	1		
Philippines	16		1	50	
Poland	26	1	6		3
Portugal	10	1	1		
Qatar	1		1	3	
Republic of Moldova				1	
Romania	19		4	49	
Russian Federation	54	1	4	56	

Member State	No. of research contracts and agreements	No. of Collaborating Centres	Services provided to Member States		
			ALMERA[a]	Dosimetry audits for radiotherapy	Plant irradiation services
Rwanda					
Saint Lucia					
Saint Vincent and the Grenadines					
San Marino					
Saudi Arabia	5		1	11	
Senegal	5				
Serbia	13		5	19	1
Seychelles					
Sierra Leone					
Singapore	9		3		
Slovakia	8	1	3		2
Slovenia	12		1	3	
South Africa	32	1	3		
Spain	45	2	2		
Sri Lanka	10		1	12	
Sudan	8				
Sweden	12		2		
Switzerland	9	2	3		
Syrian Arab Republic	6		1		
Tajikistan			1		
Thailand	26	1	2	25	
Togo				1	
Trinidad and Tobago	1			4	
Tunisia	21		1	17	
Türkiye	21		2	31	
Turkmenistan					

Member State	No. of research contracts and agreements	No. of Collaborating Centres	Services provided to Member States		
			ALMERA[a]	Dosimetry audits for radiotherapy	Plant irradiation services
Uganda	8			3	
Ukraine	23		1	19	
United Arab Emirates	2	1	3	3	
United Kingdom	42	2	6		2
United Republic of Tanzania	5			5	1
United States of America	110	1	7		
Uruguay	5		1	11	
Uzbekistan			1		
Vanuatu					
Venezuela, Bolivarian Republic of			2	16	
Viet Nam	22		3	23	
Yemen					
Zambia	9		1		
Zimbabwe	5				

[a] ALMERA: Analytical Laboratories for the Measurement of Environmental Radioactivity.

Table A14. Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) missions in 2021

Type	Country
ARTEMIS	Ireland
ARTEMIS	Japan

Table A15. Education and Training Appraisal (EduTA) missions in 2021

Type	Country
EduTA	Nigeria

Table A16. IAEA-designated International Centres based on Research Reactors (ICERR)

Organization/Research Centre	Country	Year of designation/ redesignation
Institute for Nuclear Research Pitesti	Romania	2020
Korea Atomic Energy Research Institute	Republic of Korea	2019
Nuclear Research Centre SCK CEN	Belgium	2017
Idaho and Oak Ridge National Laboratories of the US Department of Energy	United States of America	2017
Research Institute of Atomic Reactors	Russian Federation	2016
French Alternative Energies and Atomic Energy Commission, in partnership with the Institute for Radiological Protection and Nuclear Safety	France	2015 / 2020

Table A17. Integrated missions of the Agency's Programme of Action for Cancer Therapy (imPACT) in 2021

Type	Country
imPACT	Democratic Republic of Congo
imPACT	Iraq
imPACT	Nepal
imPACT	Uruguay

Table A18. Integrated Nuclear Infrastructure Review (INIR) missions in 2021

Type	Country
INIR Phase 1	Uganda
INIR Phase 1 Follow-up	Kenya
INIR Phase 2	Uzbekistan

Table A19. Integrated Nuclear Infrastructure Review for Research Reactors (INIR-RR) missions in 2021

Type	Country
INIR-RR	Thailand

Table A20. International Nuclear Management Academy (INMA)

Type	Organization/Research Centre	Country	Year of Mission
INMA	Sofia University "St. Kliment Ohridski"	Bulgaria	2021
INMA	University of West Bohemia	Czech Republic	2021

Table A21. Integrated Safety Assessment of Research Reactors (INSARR) missions in 2021

Type	Country
INSARR	Netherlands

Table A22. International Physical Protection Advisory Service (IPPAS) missions in 2021

Type	Country
IPPAS	Belarus
IPPAS	Burkina Faso
IPPAS	Czech Republic
IPPAS	Niger
IPPAS	Senegal
IPPAS	Türkiye

Table A23. Integrated Regulatory Review Service (IRRS) missions in 2021

Type	Country
IRRS	Denmark
IRRS	Switzerland
IRRS follow-up	Belarus
IRRS follow-up	Cameroon

Table A24. Knowledge Management Assist Visit (KMAV) missions in 2021

Type	Organization/nuclear power plant	Country
KMAV Level 1	Institute of Radiation Protection and Dosimetry	Brazil
KMAV Level 3	Budapest University of Technology and Economics	Hungary
KMAV Level 2 and 3	Nuclear Energy Agency of Indonesia and other national organizations involved with developing the national nuclear programme	Indonesia
KMAV Level 1	Jordan Atomic Energy Commission, Energy and Minerals Regulatory Commission, Jordan Uranium Mining Company, Jordan Research and Training Reactor	Jordan
KMAV Level 1	Laguna Verde NPP and National Institute for Nuclear Research	Mexico
KMAV Level 1	Nuclear Power General Directorate, Nuclear and Radiological Regulatory Authority, Sudan Atomic Energy Commission and Sudanese Thermal Power Generating Co. Ltd.	Sudan
KMAV Level 1	State Committee on Industrial Safety, Uzatom Agency, Academy of Science INP, State Committee on Ecology and Environment Protection, Ministry of Health, Ministry of Emergency Situations	Uzbekistan

Table A25. Operational Safety Review Team (OSART) missions in 2021

Type	Country
OSART	France
OSART	France
OSART	Russian Federation
OSART follow-up	Belarus
OSART follow-up	France
OSART follow-up	Russian Federation
OSART follow-up	Slovakia

Table A26. Safety Aspects of Long Term Operation (SALTO) missions in 2021

Type	Country
SALTO	Bulgaria
SALTO	Slovenia
SALTO	Spain
SALTO follow-up	Argentina
SALTO follow-up	Armenia
SALTO follow-up	Sweden

Table A27. Safety Culture Continuous Improvement Process (SCCIP) missions in 2021

Type	Country
SCCIP	Mexico

Table A28. Site and External Events Design (SEED) missions in 2021

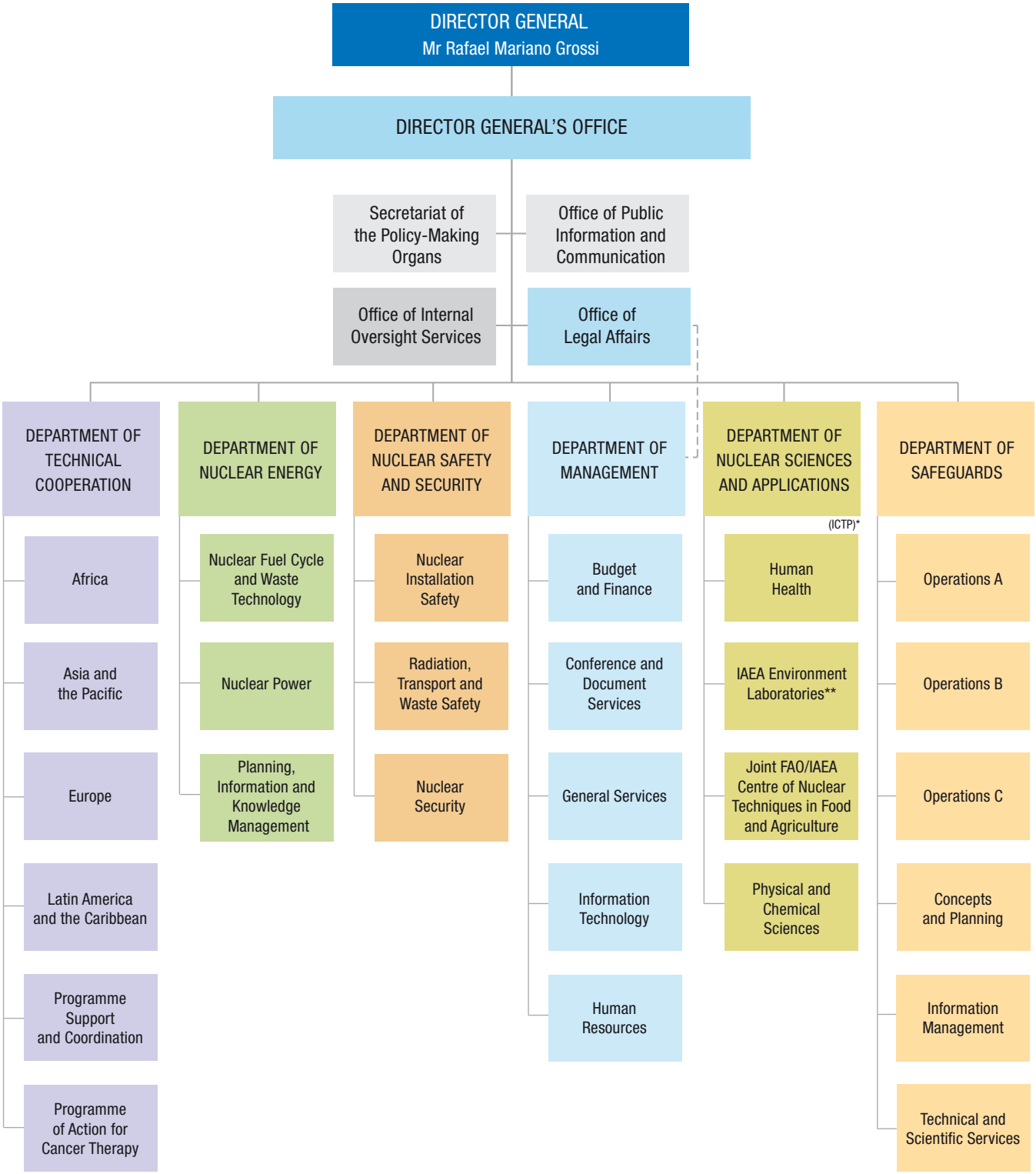
Type	Country
SEED	Hungary
SEED	Kenya
SEED	Uzbekistan
SEED follow-up	Kenya
SEED follow-up	Türkiye

Table A29. Technical Safety Reviews (TSRs) in 2021

Type	Country
Probabilistic Safety Assessment	Hungary

ORGANIZATIONAL CHART

(as of 31 December 2021)



* The Abdus Salam International Centre for Theoretical Physics (ICTP), legally referred to as the "International Centre for Theoretical Physics", is operated as a joint programme by UNESCO and the Agency. Administration is carried out by UNESCO on behalf of both organizations.

** With the participation of UNEP and IOC.

"The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world."

Article II of the IAEA Statute

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