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(GC(66)/1 and Add.1)

# Strengthening the Agency's Activities related to Nuclear Science, Technology and Applications

*Report by the Director General*

## Summary

In response to General Conference resolutions GC(65)/RES/11, GC(63)/RES/10 and GC(62)/RES/9, this document contains progress reports on:

- Part A: Non-Power Nuclear Applications
  - General (Annex 1)
  - Support to the African Union's Pan African Tsetse and Trypanosomosis Eradication Campaign (AU-PATTEC) (Annex 2)
  - Renovation of the Agency's Nuclear Applications Laboratories at Seibersdorf (Annex 3)
  - Development of the Sterile Insect Technique Package for the Management of Disease-Transmitting Mosquitoes (Annex 4)
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- Part C: Nuclear Knowledge Management
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Further information on the Agency's activities related to nuclear science, technology and applications can be found in the *Nuclear Technology Review 2022* (document GC(66)/INF/4); the *IAEA Annual Report 2021* (GC(66)/4), in particular the section on nuclear technology; and the *Technical Cooperation Report for 2021* (GC(66)/INF/7).

### Recommended Action

- It is recommended that the Board of Governors take note of this report.

# General

## Non-power nuclear applications

### **A. Background**

1. In resolution GC(65)/RES/11.A.1, the General Conference requested the Director General, in conformity with the Statute, to continue to pursue, in consultation with Member States, the Agency's activities in the areas of nuclear science, technology and applications, with special emphasis on supporting the development of nuclear applications in Member States with a view to strengthening infrastructures and fostering science, technology and engineering for meeting sustainable growth and development needs of Member States in a safe manner.
2. The General Conference recommended that the Secretariat report to the Board of Governors and to the General Conference at its sixty-sixth (2022) regular session on the progress made in the areas of nuclear science, technology and applications. This report has been prepared in response to that recommendation.

### **B. Progress since the 65th Regular Session of the General Conference**

3. The Agency, as a member of the United Nations Crisis Management Team for COVID-19 and in coordination with the World Health Organization (WHO), continued providing assistance to Member States in fighting COVID-19 through the provision of equipment and training.
4. The Agency responded to requests from 129 countries and territories for assistance during the COVID-19 pandemic. Besides supplying related equipment such as reverse transcription–polymerase chain reaction instruments, the Agency continued, through webinars, to assist health care providers around the world to adjust their standard operating procedures to cope with the pandemic and to continue delivering their services. COVID-19 support was provided to more than 300 medical and veterinary laboratories. More than 2036 consignments of equipment and supplies for detecting and diagnosing COVID-19 were delivered to 129 countries and territories.
5. The Agency continued to validate the most promising COVID-19 detection kits to determine their sensitivity and specificity performance as they became available on the market. Fifty-one Veterinary

Diagnostic Laboratory (VETLAB) Network laboratories are currently supporting their human diagnostic laboratory counterparts in the testing of COVID-19.

6. The Agency organized an International Symposium on Managing Land and Water for Climate-Smart Agriculture in July 2022 to advance the understanding, collaboration, and capabilities of countries to respond to the impact of climate change and a rapidly changing global environment.

7. The Agency continued to support food safety and quality control systems critical to protecting consumers, facilitating global trade among Member States, and building resilience to crises affecting the food supply chain. Rapid, field-deployable methods for verifying rice origin and authenticating commodities such as coffee, organic orange juice and strawberries to combat food fraud, and for the detection of heavy metals, aflatoxins and pesticides were developed.

8. Laboratory networks for food safety were further strengthened in Africa, Asia and the Pacific, and Latin America and the Caribbean through Agency support to over 205 food safety and control institutions. In addition, a plant mutation breeding network established in the Asia and the Pacific region in 2019 continue to be supported, along with another that was formalized for Latin America in 2020.

9. The Agency continued to collaborate with designated Member State institutions to implement the Agency's programmatic activities and promote the practical use of nuclear techniques. At the end of 2021, the Agency had 56 active Collaborating Centres (40 of which in fields related to non-power nuclear applications) in 29 Member States — an increase of three compared to the end of 2020. At the end of 2021, the Agency operated 1728 active research contracts and agreements in 114 Member States as part of 133 active coordinated research projects (CRPs), of which 105 were related to non-power nuclear applications.

10. The Agency, through its IAEA Marine Environment Laboratories, supported coordination among United Nations agencies as a member of the UN-Oceans mechanism, the United Nations Environment Management Group and the Consultative Process on a Pollution-Free Planet, thereby contributing to the preparatory work for an international legally binding instrument to end plastic pollution, including in the marine environment, in line with a resolution adopted by countries in the fifth session of the United Nations Environment Assembly.<sup>1</sup>

11. The Agency set up the NUClear TEChnology for Controlling Plastic Pollution (NUTEC Plastics) to assist Member States in integrating nuclear techniques as part of their efforts to address the challenges of plastic pollution. In 2021, the Agency held four regional roundtable discussions with ministers, high level officials and experts from industry and academia from Asia and the Pacific, Africa, North, Central and South America and the Caribbean, and Europe and Central Asia, as well as from international organizations to discuss ongoing efforts, innovative solutions and partnerships to tackle plastic pollution. Follow-up actions in all four regions have been initiated following the roundtable discussions. For the first time, NUTEC Plastics was also featured at the UN Ocean Conference in June 2022 amidst international experts, ministers, scientists and global leaders who came together to address ocean acidification, deoxygenation and ocean warming.

12. The Agency, through its Ocean Acidification International Coordination Centre (OA-ICC), continued to support Member States and to provide access to ocean acidification publications and data through a data portal on ocean acidification biological response, organized specialized training and contributed to relevant sessions during COP26.

13. The Agency continued to support regional marine programmes such as the United Nations Environment Programme (UNEP) Mediterranean Action Plan, the Convention for the Protection of the

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<sup>1</sup> UNEP/EA.5/L.23/Rev.1

Marine Environment of the North-East Atlantic, the Convention on the Protection of the Marine Environment of the Baltic Sea Area, and international conventions such as the Minamata Convention on Mercury and the Stockholm Convention on Persistent Organic Pollutants by providing matrix certified reference materials of high quality through interlaboratory comparisons for the analysis of contaminants in marine matrices.

14. In a series of webinars conducted in 2021, methodologies for monitoring and determining trace elements and organic contaminants in the marine environment were delivered to laboratory practitioners from Mediterranean countries as a part of the Agency's cooperation with UNEP under the Programme for the Assessment and Control of Pollution in the Mediterranean Region.

15. The Agency hosted the 48th annual session of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), held virtually in September 2021. The new GESAMP Working Group 45 on Climate Change and Greenhouse Gas Related Impacts on Contaminants in the Ocean was formed in 2021 and is co-sponsored by the Agency (as lead agency), UNEP, the Intergovernmental Oceanographic Commission, the International Maritime Organization, and the World Meteorological Organization (WMO).

16. The Analytical Laboratories for the Measurement of Environmental Radioactivity (ALMERA) network, which was established by the Agency, has further grown to encompass 195 laboratories in 90 Member States. More than 100 ALMERA network laboratories participated in the recent annual proficiency test to demonstrate their technical competence. Over 300 further laboratories joined a related worldwide open proficiency test on analysis of environmental radionuclides.

17. The Agency continued to carry out research in analytical techniques using radio- and stable isotopes to advance knowledge of the provenance, bioaccumulation and transfer of contaminants, such as heavy metals, persistent organic pollutants, microplastics and biotoxins in the marine environment and specifically seafood, in order to minimize the health risks from the consumption of contaminated seafood.

18. In the reporting period, a reference material for mercury was established to support high precision monitoring of mercury in the marine environment. One global interlaboratory comparison on trace elements and mercury in marine biota was completed to enhance the capabilities of monitoring laboratories to report reliable data.

19. The Agency, through its Marine Radioactivity Information System (MARIS), continues to support marine research and monitoring initiatives in Member States through the provision of verified data and information on levels of radioactivity in the world's oceans. The MARIS website functionality was significantly developed to improve its structure and make it more informative and easier to use.

20. The Agency continued to strengthen its relationships with the WMO and the International Bureau of Weights and Measures (BIPM) in the area of climate change by cooperating to extend the global isotopic monitoring of methane as an atmospheric greenhouse gas and by testing the capabilities for carbon dioxide isotope analysis of leading institutions. New Agency stable isotopic calibration tools for the atmospheric greenhouse gases carbon dioxide and methane were presented for the first time at a workshop on climate action in September 2022 organized by the WMO and BIPM.

21. The Agency's accreditation for the production of certified reference materials for environmental radionuclides was achieved in May 2022 as a result of a multi-year effort. This is a key step to further improve support to analytical laboratories worldwide by enhancing the value of produced certified reference materials.

22. The Agency continued to support the harmonization of radiotherapy dosimetry worldwide through the IAEA/WHO postal dosimetry audit service as well as through strengthening capacities of Member

States in the areas of dosimetry and medical radiation physics, by developing and updating dosimetry codes of practice, providing guidelines, conducting training events, and developing educational material to support the medical physics profession, and quality and safety in radiation medicine.

23. New learning modules in nutrition, nuclear medicine and diagnostic imaging, radiotherapy and medical physics were developed for the Human Health Campus. In parallel, new tutorial videos were published on radiotherapy and diagnostic radiology medical physics.

24. In the field of nutrition, the Agency signed Practical Arrangements with key institutions such as the British Nutrition Society, the Federation of African Nutrition Societies, and the Federation of European Nutrition Societies. Publications were developed on energy expenditure building on the Agency's new Doubly Labelled Water Database. This helps to enhance the understanding of energy metabolism and how to plan interventions to prevent and manage obesity.

25. The Agency continued to disseminate information about the benefits of nuclear medicine and radiotherapy in cancer care through networks including with United Nations organizations, such as WHO and the Joint United Nations Programme on HIV/AIDS, the Union for International Cancer Control, and the International Agency for Research on Cancer, as well as with other development partners, scientific societies, and patient advocacy groups.

26. The Agency continued to support the Master of Advanced Studies in Medical Physics including by advising on the educational programme content and its alignment with the Agency's guidelines and providing fellowships through the technical cooperation programme.

27. The Agency continued collaboration with WHO by providing technical support for the Cervical Cancer Elimination Initiative, the Global Initiative for Childhood Cancer and the Global Breast Cancer Initiative, the development of CRPs in nutrition to understand the link between early life nutrition and later childhood health, and coordination of the IAEA/WHO SSDL Network. Publications, technical briefs, and cancer prioritization and assessment tools were launched in 2022 to support the implementation of the global cancer initiatives in Member States in the areas of radiotherapy, radiology and medical imaging, and nuclear medicine. The Agency and WHO also developed dedicated guidance documents to address good manufacturing practices specific to investigational radiopharmaceuticals used in both early and late clinical trials.

28. The Agency is working through Rays of Hope, an initiative launched during the African Union Summit in February 2022, to support Member States in increasing access to affordable, equitable, effective, and sustainable radiation medicine services within a comprehensive cancer control system. The Agency has conducted detailed technical assessments for countries that have approached the Agency for support under Rays of Hope to assess their needs in an integrated way and prepare a plan of action. The Agency and WHO released a joint statement on reducing inequity in access to cancer care through the Rays of Hope initiative with the goal to upscale the long-standing and close collaboration toward common goals and accelerating progress toward the achievement of the 2030 UN Agenda for Sustainable Development.

29. The Directory of Radiotherapy Centres (DIRAC) remains the only database containing information about radiotherapy equipment worldwide. Functionalities of DIRAC were expanded to ensure effective national radiotherapy planning and efficient use of existing resources.

30. Due to the increasing significance of artificial intelligence (AI) as a 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 in October 2021. With regard to nuclear applications, the meeting identified potential areas for new activities on artificial intelligence 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 Zoonotic Disease Integrated Action (ZODIAC) initiative, optimizing smart agricultural practices, and other applications that require the processing of large amounts of data.

31. The Agency joined the 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 entitled United Nations Activities on Artificial Intelligence (AI) published by ITU, which included findings from the Agency's Technical Meeting.

32. The Agency has been designated as a member of the external expert advisory group of the European medical isotope programme "Production of High Purity Isotopes by Mass Separation for Medical Application" to strengthen good practices in handling novel radionuclides and their production for diagnostic and therapeutic purposes.

33. To strengthen the Agency's activities in the field of non-destructive testing (NDT), the Agency conducted two meetings on the application of NDT for civil engineering structures and on the development of a syllabus on radiography for cultural heritage applications. The reports from these meetings are helping the establishment of relevant frameworks for these techniques and to support Member States in their application.

34. A workshop and a technical meeting on the preservation and consolidation of cultural heritage were held in November 2021 in Grenoble, France, with the French Alternative Energies and Atomic Energy Commission to discuss the latest achievements in cultural heritage preservation using radiation technology and to define coordinated research activities. The event was attended by 114 participants (in-person and virtually) from around the world.

35. The Agency organized the Second International Conference on Applications of Radiation Science and Technology in August 2022 at IAEA Headquarters in Vienna. The conference was attended by 550 participants from 82 Member States. Over 190 oral presentations and 350 poster presentations addressed current trends and advances in radiation science and technology.

36. As part of the Agency's efforts to advance the NUTEC Plastics related activities, the Agency launched a CRP on the recycling of polymer waste for structural and non-structural materials using ionizing radiation. The first Research Coordination Meeting was held in Vienna in April 2022 and saw the attendance of 18 Member States from across the globe. Two meetings highlighting recent achievements in radiation-processed products from natural polymers have also been conducted to strengthen the generation of bio-based products for replacing single use petrol-based products.

37. The Agency continued to strengthen the use of well-accepted, frequently used therapeutic radioisotopes worldwide, such as lutetium-177, through the development of a comprehensive report on the production of lutetium-177 and lutetium-177 radiopharmaceuticals that was generated as a result of a technical meeting in November 2021 with 22 experts from 15 Member States.

38. With regard to the use of radiation technology and nuclear science, the Agency and the United Nations Interregional Crime and Justice Research Institute (UNICRI) signed a Memorandum of Understanding on the use of nuclear science and technology in the context of criminal investigations. The University of Paris-Saclay, France, was designated a Collaborating Centre for atoms for heritage, and South Africa's iThemba Laboratory for Accelerator-Based Sciences was designated a Collaborating Centre for accelerator-based scientific research and applications.

39. The Agency developed two IAEA Technical Documents entitled Compact Accelerator Based Neutron Sources (IAEA-TECDOC-1981) and Development of Steady State Compact Fusion Neutron Sources (IAEA-TECDOC-1998).

40. In May 2022, the Agency held the International Conference on Accelerators for Research and Sustainable Development: From Good Practices Towards Socioeconomic Impact in Vienna, Austria. The conference, which is the first of its kind for the Agency on this topic, highlighted the diversity of accelerator applications and the support that the Agency offers countries in developing and making use of accelerator technology. The five-day event attracted close to 500 experts from 72 countries in person and online, including research scientists engaged in accelerator-based research and applications, accelerator operators and users, entrepreneurs and stakeholders involved in applications of accelerator technologies, and policy makers and regulators.

41. In November 2021, the Agency commissioned its deuterium–deuterium based neutron generator as part of the Neutron Science Facility in Seibersdorf. This new infrastructure will allow the Agency to offer training and diverse practical applications using neutrons, such as neutron activation analysis, neutron radiography/tomography, delayed neutron counting, and neutron detection experiments.

42. The Agency released the Nuclear Reaction Data Explorer, a new web-tool through which experimental reaction data derived from the Experimental Nuclear Reaction Data database and evaluated reaction data derived from the Evaluated Nuclear Data File database can be plotted.



# Support to the African Union's Pan African Tsetse and Trypanosomosis Eradication Campaign (AU-PATTEC)

## A. Background

1. In resolution GC(65)/RES/11/A.2, the General Conference recognized that tsetse flies and the trypanosomosis problem which they cause constitute one of the greatest constraints on the African continent's socio-economic development, affecting the health of humans and of livestock, limiting sustainable rural development, and thus causing increased poverty and food insecurity.
2. The General Conference requested the Agency and other partners to strengthen capacity building in Member States for informed decision-making regarding the choice of tsetse and trypanosomosis strategies and the cost-effective integration of sterile insect technique (SIT) operations in area-wide integrated pest management (AW-IPM) campaigns. The General Conference also requested the Secretariat, in cooperation with Member States and other partners, to maintain funding through the Regular Budget and the Technical Cooperation Fund for consistent assistance to selected operational SIT field projects and to strengthen its support for research and development and technology transfer to African Member States to complement their efforts to create and subsequently expand tsetse-free zones.
3. The General Conference, in resolution GC(65)/RES/11.A.2, requested the Director General to report on the progress made in the implementation of this resolution to the Board of Governors and to the General Conference at its sixty-sixth (2022) regular session.

## B. Progress since the 65th Regular Session of the General Conference

### B.1. Strengthening Collaboration with AU-PATTEC

4. The Agency continued to hold virtual meetings with AU-PATTEC on the status of the activities of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture and the Agency's assistance provided under the technical cooperation programme in support of tsetse and trypanosomosis control. The Agency also continued its close collaboration with AU-PATTEC on its goal to eliminate tsetse flies and trypanosomosis through the creation of sustainable tsetse and trypanosomosis free areas.

### B.2. Capacity Building through Applied Research and Technical Cooperation

5. The Agency continued to respond to Member States' requests for support in incorporating SIT into AW-IPM through regional project RAF/5/080 "Supporting Area-Wide Tsetse and Trypanosomosis Management to Improve Livestock Productivity - Phase IV" for 2018–2021 and the new regional project RAF/5/087 "Enhancing Regional Capacity for the Implementation of the Sterile Insect Technique as a Component for Area-Wide Tsetse and Trypanosomosis Management" for 2022–2025 to eliminate or

control tsetse-transmitted trypanosomosis. The disease is recognized as a major constraint on both livestock and agricultural crop production in sub-Saharan Africa. The support has included the provision of technical advice, procurement of equipment and materials, training courses and workshops, fellowships and scientific visits through the relevant technical cooperation projects, and research that was conducted at the Insect Pest Control Laboratory (IPCL) at the FAO/IAEA Agriculture and Biotechnology Laboratories in Seibersdorf, Austria. In addition, experts from affected Member States continued to participate in the coordinated research project entitled “Improvement of Colony Management in Insect Mass Rearing for Sterile Insect Technique Applications”, which includes a research group on tsetse flies.

6. The Agency’s support strengthened capacities in Member States, enabling them to obtain and analyse baseline data to support informed decision-making regarding the choice and feasibility of available tsetse and trypanosomosis suppression or eradication strategies, including the cost-effective integration of SIT operations into AW-IPM campaigns. In that context, the Agency continued providing support to Burkina Faso, Chad, Senegal, South Africa, Uganda, the United Republic of Tanzania, Zambia, and Zimbabwe.

7. Research activities at the IPCL continued to focus on improving sterile male quality by refining sterilization protocols and understanding the impact of pathogenic viruses and symbiotic bacteria on the productivity and performance of tsetse colonies.

8. Species-specific sorting protocols for the Near Infrared Pupae Sex Sorter units for the tsetse fly are currently in operation in two insectaries that produce tsetse pupae for the AW-IPM campaign currently under way in the Niayes region of Senegal, to the north-east of Dakar. Units were also provided to Burkina Faso and Ethiopia.

9. Advances in knowledge and applicable technologies arising from the above-mentioned research activities are being widely disseminated through publications in peer-reviewed scientific journals, as well as through conference presentations.

### **B.3. Support for the Planning and Implementation of SIT Activities**

10. Under regional project RAF/5/080, the Agency continued to provide training in supporting area-wide tsetse and trypanosomosis management to improve livestock productivity and to supply equipment and consumables for field entomological surveillance activities and the operation of mass rearing insectaries and molecular biology laboratories in Angola, Burkina Faso, Cameroon, Chad, the Democratic Republic of the Congo, Ethiopia, Ghana, Kenya, Mali, Nigeria, Senegal, Uganda, the United Republic of Tanzania, Zambia, and Zimbabwe. The irradiation capacities at the tsetse insectaries of the United Republic of Tanzania and the International Centre of Research and Development for Livestock in Subhumid Zones were strengthened through the replacement of non-functional irradiators. Capacity building activities also included one regional training course to support drone operations targeting the release of sterile flies in tsetse and trypanosomosis pilot projects in Burkina Faso, Chad, Ethiopia, Uganda, the United Republic of Tanzania, and Zimbabwe.

11. Through the technical cooperation programme, the Agency continued to provide technical support to Senegal in its efforts to eradicate *Glossina palpalis gambiensis*, a species of tsetse fly, from the highly productive agricultural region of Niayes, to the north-east of Dakar, using an AW-IPM approach with an SIT component. Tsetse fly populations have been suppressed in 99% of the target area and transmission of trypanosomosis has stopped. Senegal continues to import more productive cattle into the area.

12. In Chad, pre-operational activities have continued in the Mandoul area, one of the country’s few remaining active foci of sleeping sickness. Suppression activities have continued, resulting in an

extremely low density of tsetse flies and the lowest number of cases of sleeping sickness in this focus, which consists of areas for which historical records of disease transmission are available. Options for the upscaling of the colony to produce sterile males are being explored. Training activities on the maintenance of tsetse colonies, the sorting and sterilization of tsetse pupae and the long-distance shipment of sterile pupae have continued. A field insectarium in Doba that can process 10 000 pupae per week was supplied with tsetse rearing equipment. Procedures for the purchase of a long-range drone and training on its operation have been initiated with the aim of reducing the cost of the upcoming operational phase.

13. African trypanosomosis affecting livestock continues to pose a significant constraint on development in much of sub-Saharan Africa, especially in rural areas. Where technically feasible, SIT, as a component of AW-IPM interventions, can be a significant tool for alleviating this constraint. It provides an environmentally friendly option for eradicating tsetse fly vector populations, removing the risk not only of animal trypanosomosis, but also of human trypanosomosis (sleeping sickness) where it occurs. The benefits achieved, such as the improved ability to rear livestock for milk, meat and animal traction for ploughing to grow crops, will substantially improve the livelihoods of rural populations. The Agency continues to assist in building capacity in this area for the benefit of Member States in sub-Saharan Africa.

14. The constraints on successful and more widespread application of SIT in suitable areas continue to be the shortage of mass rearing capacity in Africa and of appropriate management structures for mass rearing and area-wide pest control operations.



# Renovation of the Agency's Nuclear Applications Laboratories at Seibersdorf

## A. Background

1. During the 56th regular session of the General Conference in September 2012, the Director General called for an initiative to modernize and renovate the eight laboratories of the Department of Nuclear Sciences and Applications in Seibersdorf, Austria, to enable them to meet the growing and evolving needs of Member States. The General Conference supported the initiative of the Director General in resolution GC(56)/RES/12.A.5, and the Renovation of the Nuclear Applications Laboratories (ReNuAL) project which was officially launched on 1 January 2014. The strategy for the project was issued in May 2014 in documents GOV/INF/2014/11 and GOV/INF/2014/11/Corr.1.
2. ReNuAL Plus (ReNuAL+) was delineated in an addendum to the strategy that was issued in September 2014 (document GOV/INF/2014/11/Add.1) to provide for improvements required by the laboratories that could not be accommodated within the scope of the ReNuAL project. In February 2017, the Secretariat issued document GOV/INF/2017/1, Renovation of the Nuclear Applications Laboratories (ReNuAL) Project, which updated Member States on the status of ReNuAL and ReNuAL+ and provided details on the implementation of ReNuAL, the scoping and costing of ReNuAL+, and efforts on resource mobilization.
3. The combined ReNuAL/ReNuAL+ phase of the initiative delivered new laboratory buildings to house four of the eight nuclear applications laboratories in Seibersdorf and provided a new linear accelerator facility for the Agency's Dosimetry Laboratory. It was expected that the four remaining laboratories would be expanded, and core infrastructure enhanced in the existing buildings once the other laboratories then sharing those facilities moved into their new space. However, in early March 2020, an assessment by external experts concluded that the full renovation of the existing 60-year-old laboratory building, intended to make the laboratories 'fit for purpose' to support Member State requirements, would likely take longer, cost more and result in a lower-quality laboratory building than the construction of a new building to house three of the laboratories (the Terrestrial Environment Laboratory, the Plant Breeding and Genetics Laboratory, and the Nuclear Science and Instrumentation Laboratory). The ReNuAL project management team determined the conclusions of the experts to be appropriate and concurred that a new building was the most suitable option for enhancing the three laboratories.
4. In that context, at the March 2020 meetings of the Board of Governors, the Director General announced plans to build a second new Flexible Modular Laboratory (FML-2) building, which will house the three above-mentioned laboratories. The Dosimetry Laboratory will be refurbished in its current location adjacent to its new linear accelerator facility. Ageing greenhouses, on which the work of three laboratories heavily depends, will also be replaced. The Director General provided information on the resources required and further elaborated planning for this final phase of the project, known as 'ReNuAL 2', during a technical briefing on 3 September 2020. The successful conclusion of this final project phase will enable the nuclear applications laboratories to respond to the growing and evolving needs of Member States and assist their efforts to achieve the Sustainable Development Goals.
5. The General Conference, in resolution GC(65)/RES/11/A.3, requested the Director General to report on the progress made in the implementation of this resolution to the Board of Governors and to the General Conference at its sixty-sixth (2022) regular session.

## B. Progress since the 65th Regular Session of the General Conference

### B.1. Implementation Status

6. Design planning for the three main elements of ReNuAL 2 (i.e., the FML-2 building, greenhouses, and Dosimetry Laboratory refurbishment) was concluded with the assistance of an external architectural firm in May 2021. The preparation of tender documents was completed and an open bidding process was launched in November 2021 for construction of the new laboratories building, refurbishment of the Dosimetry Laboratory, and construction of a foundation for the new greenhouses. The procurement process is ongoing as of the beginning of the third quarter of 2022, with the aim of breaking ground on this work at the end of 2022. Due to their specialized design and function, the greenhouses, apart from their foundation, will be constructed under a separate contract to be offered for tender following conclusion of the ongoing procurement process. The project implementation schedule will be adjusted based on the start date of construction.

### B.2. Financial Status and Resource Mobilization

#### B.2.1. Financial Status

7. Over €39 million in extrabudgetary funds were raised for ReNuAL and ReNuAL+, with financial and in-kind contributions received from 42 Member States, and additional financial and in-kind support received from non-traditional donors. The combined ReNuAL/ReNuAL+ project target budget of €57.8 million was exceeded by approximately €470 000. Approximately €9.7 million of this project budget remain available to address the requirements of the four remaining laboratories in the ReNuAL 2 project phase, which will include the construction of a new laboratories building (FML-2), construction of new greenhouses, refurbishment of the Dosimetry Laboratory, and additional infrastructure work.



*FIG. B.1. Architect's rendering of the main element of ReNuAL 2 (Source: IAEA)*

8. Preliminary cost estimates totalling €34.5 million for the final phase of laboratory modernization were provided to Member States in the Director General's technical briefing in September 2020. With €9.7 million already available from the ReNuAL/ReNuAL+ budget to address the needs of these laboratories, the Director General requested Member State support to raise the remaining €24.8 million. As of the June 2022 Board of Governors meeting, 27 Member States and one international organization

had announced extrabudgetary contributions for the ReNuAL 2 phase totalling nearly €17.5 million. An additional €3.1 million in funding for ReNuAL 2 will be provided from the Major Capital Investment Fund. The actual outstanding funding requirement will be known only at the conclusion of the ongoing procurement process for the construction of the new laboratories building, Dosimetry Laboratory refurbishment, greenhouses foundation, and future contract negotiations for the new greenhouses, which are taking place in the context of a rapid price escalation.

### **B.2.2. Funding Priorities**

9. A Member State contribution to ReNuAL 2 announced during the 64th regular session of the General Conference included funding for the refurbishment of the Dosimetry Laboratory. The remaining funding estimated to be needed for the construction of the new laboratories building was mobilized through pledges jointly announced by eight Member States during the March 2022 Board of Governors meeting and commemorated at the ReNuAL2 Side Event which was held on the margins of the June Board of Governors Meeting. The current objective is to mobilize funding needed by the fourth quarter of 2022 for replacement of the greenhouses. The initial estimate for this work was €5 million; however, the total cost is now projected to be approximately €6 million owing to continuing price escalation in the construction and supplies markets.

### **B.2.3. Resource Mobilization Strategy**

10. The Secretariat has pursued an element-specific resource mobilization strategy that seeks resources from Member States and non-traditional donors based on existing funding requirements. In support of this strategy, new and targeted resource mobilization products have been developed to highlight the importance of the timely completion of laboratory modernization and the relevance of individual project elements to meeting Member States' demands for training, applied research and services. Tailored donor packages include comprehensive information on the remaining elements of the project and their funding requirements. Resource mobilization products are continually updated to account for progress in completing specific project elements, any changes in expected costs, and expected resource requirements.

11. Laboratory tours remain invaluable to highlight the important work of the laboratories and play an essential role in fundraising efforts; however, laboratory visits were suspended and then resumed on a much more limited basis as circumstances permitted for much of the period since the beginning of the COVID-19 pandemic. In response, the Secretariat continues to develop and expand access to online resources, including virtual laboratory tours. Special events organized by the Secretariat, including side events at the General Conference in 2021 and at the November 2021 and June 2022 Board of Governors meetings, provided valuable additional support to resource mobilization efforts. A centrepiece of these events is a donor display on which new contributors to ReNuAL 2 are recognized with a 'national plaque.' The donor display will be permanently installed in the lobby of the new FML-2 building upon its completion.



*FIG. B.2. A ReNuAL2 Side Event was held on the margins of the June Board of Governors Meeting held at the Agency headquarters in Vienna, Austria. 7 June 2022 (Source: IAEA)*

#### **B.2.4. Resource Mobilization Efforts with Member States**

12. The Secretariat continued to engage in bilateral discussions with a large number of Member States to support fundraising, resulting in 42 Member States providing financial contributions towards the ReNuAL and ReNuAL+ phases of the initiative and 27 Member States so far announcing contributions to the ReNuAL 2 phase. The Friends of ReNuAL, an informal group open to all Member States and co-chaired by Germany and South Africa, continued to play an important role in resource mobilization. Participants in the Friends group, which meets on a regular basis, have been significant bilateral contributors to the ReNuAL initiative, and the group remains an important vehicle for maintaining and increasing awareness of the importance of laboratory modernization and for generating Member State support for these efforts.

#### **B.2.5. Resource Mobilization Efforts with Non-Traditional Donors**

13. The announcement of the remaining equipment requirements for the nuclear applications laboratories continues to be posted on the United Nations Global Marketplace to maximize the potential of generating private sector interest in partnering with the Secretariat.



## C. Next Steps

14. Procurement for construction of the new FML-2 laboratories building, Dosimetry Laboratory refurbishment, and foundation for the future greenhouses is ongoing as of the beginning of the third quarter of 2022. Upon successful conclusion of this process construction will be launched on these project elements and a tendering process will subsequently begin for procurement of the greenhouses.

15. Resource mobilization efforts will focus on raising, by the fourth quarter of 2022, the €6 million, now projected to be required to procure and launch construction of the greenhouses in the first half of 2023.



# Development of the Sterile Insect Technique Package for the Management of Disease-Transmitting Mosquitoes

## A. Background

1. In resolution GC(62)/RES/9.A.2, the General Conference noted with concern that about 3.2 billion people remain at risk of malaria, transmitted by mosquitoes, and that in 2016 alone there were an estimated 216 million new cases of malaria and 445 000 deaths, mainly in Africa, thus constituting a major obstacle to poverty eradication in Africa. It noted that the malaria parasite has continued to develop resistance to drugs and that mosquitoes have continued to develop resistance to insecticides.
2. The General Conference noted with serious concern that, in recent years, mosquito-transmitted dengue, now the world's most common mosquito-borne disease, has become a major international public health concern with an incidence growing more than 30-fold during the last 50 years, and that dengue is estimated to infect around 400 million people per year, and over half of the world's population is at risk of the disease.
3. The General Conference noted that the suppression of disease-transmitting mosquitoes using the sterile insect technique (SIT) will be suitable mostly in urban areas, where aerial spraying with insecticides is prohibited or not recommended, and an area-wide approach is required, which represents a novel and potentially powerful supplement to existing community-based programmes.
4. The General Conference requested the Agency to continue and strengthen the research, both in the laboratory and in the field, required to be able to refine and validate the use of the SIT for the integrated management of malaria-, dengue-, Zika- and other disease-transmitting mosquitoes. It requested the Agency to increasingly involve developing Member States' scientific and research institutes in the research programme in order to secure their participation, leading to ownership by the affected countries. The General Conference also requested the Agency to increase efforts to develop and transfer more efficient sex separation systems, including genetic sexing strains, that allow complete removal of the female mosquitoes in production facilities and to develop cost-effective methods to release and monitor sterile males in the field.
5. The General Conference also requested the Agency to strengthen capacity building and networking in Latin America, Asia and the Pacific, and Africa through regional technical cooperation projects and to support field projects against *Aedes* and *Anopheles* mosquitoes through national technical cooperation projects for assessing the potential of the SIT as an efficient control tactic for disease-transmitting mosquitoes.
6. The General Conference noted with appreciation the interest shown by some donors in and their support for research and development (R&D) on the SIT for combating malaria-, dengue-, Zika- and other disease-transmitting mosquitoes, and requested the Agency to allocate adequate resources and to attract extrabudgetary funds so as to continue the currently expanded mosquito research programme, laboratory/office space and staffing.
7. The General Conference invited the Agency to act upon the recommendation made by the experts of the Thematic Plan for the Development and Application of the Sterile Insect Technique (SIT) and Related Genetic and Biological Control Methods for Disease Transmitting Mosquitoes to invest in

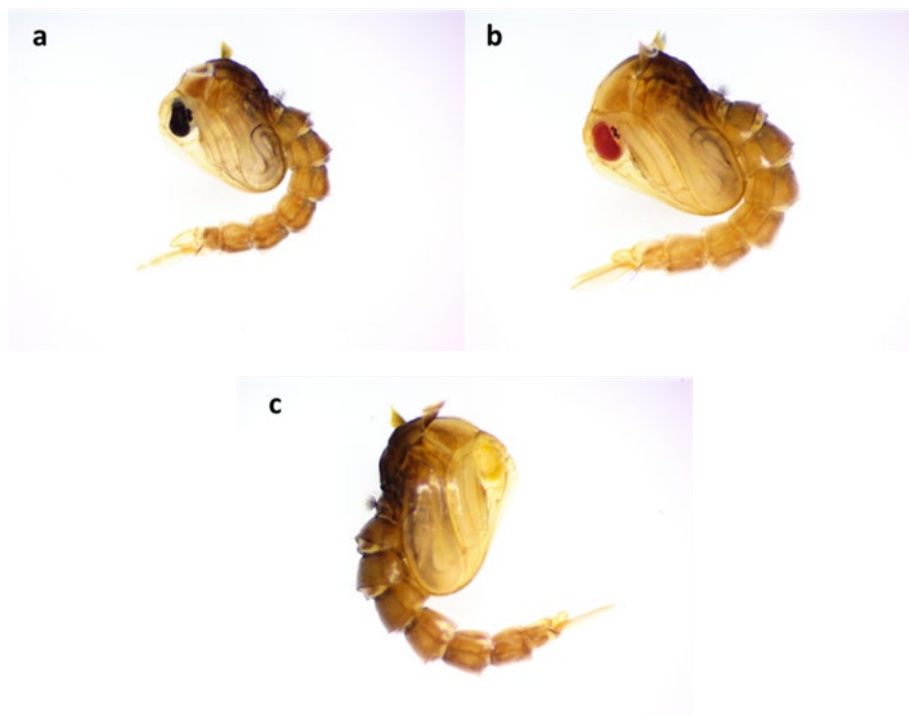
supporting the management of the mosquito vector species through continuous funding of the development of the SIT and related genetic and environment-friendly methods.”

8. The General Conference, in resolution GC(65)/RES/11.A.6, requested the Director General to report on the progress made in the implementation of resolution GC(62)/RES/9.A.2, to the Board of Governors and to the General Conference at its sixty-sixth (2022) session.

## **B. Progress since the 62nd Regular Session of the General Conference**

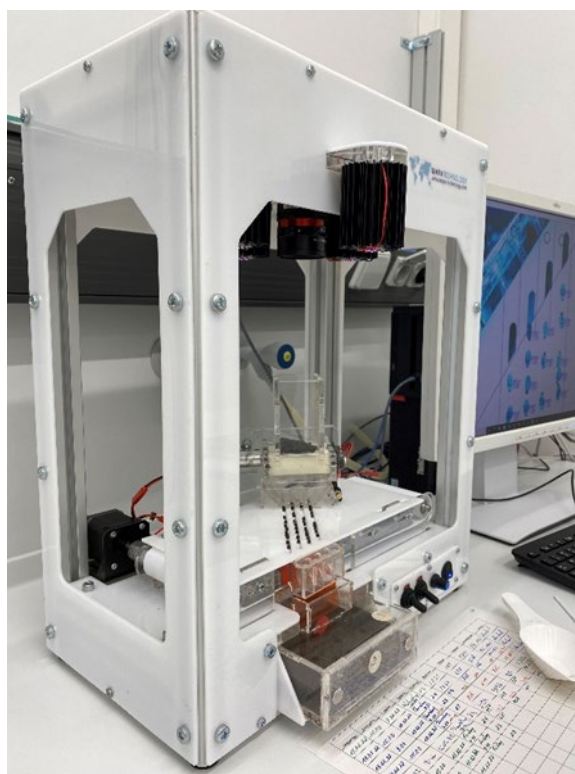
9. In response to resolution GC(62)/RES/9.A.2, the Agency, through the Insect Pest Control Laboratory (IPCL) in Seibersdorf, Austria, continued to work on the development of the SIT package for disease-transmitting mosquitoes, i.e. *Anopheles arabiensis*, which is a vector of malaria, and *Aedes aegypti* and *Aedes albopictus*, which are the main vectors of dengue, Zika, chikungunya and yellow fever. The IPCL is currently maintaining mosquito strains from 16 countries, including strains with morphological and other markers, which are currently being evaluated for their potential use in SIT-based approaches.

10. The Agency continued its efforts to develop robust and efficient methods for sex separation, including genetic sexing. Two *Aedes aegypti* genetic sexing strain (GSSs), one based on red eye colour and the other on white eye colour, were developed and validated under laboratory conditions. The *Aedes aegypti* red-eye GSS is robust; an irradiation-induced chromosomal inversion was integrated into the red-eye GSS to enhance its genetic stability. Both the red-eye selectable marker and the irradiation-induced chromosomal inversion have been introgressed into different genomic backgrounds and have maintained their functionality, both in respect to sexing properties and the long-term genetic stability. Near-infrared spectroscopy is currently being explored as a means for the development of a prototype sorter for large-scale sex sorting using the red-eye selectable marker. Mutagenesis screens as well as screening of wild populations and laboratory strains of *Aedes aegypti* are being carried out to discover novel mutations that could be used as potential selectable markers for genetic sexing as early in development as possible.



*FIG. B.1. Aedes aegypti pupae: (a) black-eye male, (b) red-eye female and (c) white-eye female.  
(Source: IAEA).*

11. In terms of mosquito mass-rearing technology, the IPCL has developed and validated several tools, pieces of equipment and procedures with the aim of reducing production costs and increasing the quality of the biological material. For example, new cages for adult *Aedes* mosquitoes and larval racks have been validated for *Aedes albopictus*, with a significant reduction in cost; an automated pupal sorter has been evaluated for two species; and a new larval diet based on inexpensive insect proteins (black soldier fly powder) has been developed for mass-rearing mosquito larval stages.



*FIG. B.2. Near Infrared Pupal Sex Sorter (NIRPSS) connected to a computer during operation.  
(Source: IAEA)*

12. Recognizing the increasing challenges associated with using isotopic irradiators for the sterilization of mosquitoes and the anticipated expansion of mosquito suppression projects, the Agency assessed the relative efficiency of X-rays and gamma rays to induce sterility in male pupae of *Anopheles arabiensis*, *Aedes albopictus* and *Aedes aegypti*. The Agency also assessed the major factors impacting the dose response and quality of insects, including the dose rate, chilling, atmospheric conditions, geographic origin, life stage and age of pupae. Furthermore, the potential for irradiating adult chilled mosquitoes or mosquitoes anaesthetized in nitrogen has been investigated. Irradiation of compacted chilled adult males in large numbers is an attractive option for field programmes. The Agency also initiated collaboration with the private sector for the development of X-ray irradiators adapted to the sterilization of mosquitoes, and an ‘off the shelf’ X-ray blood irradiator has been characterized and assessed for its applicability in mosquito sterilization.

13. A rapid quality control test that measures flight ability for *Aedes aegypti*, *Aedes albopictus* and *Anopheles arabiensis* has been developed and transferred to Member States.

14. Molecular tools to diagnose mosquito-borne diseases and pathogens in mosquito colonies were developed in collaboration with Infravec2, a research project funded by the European Commission. These molecular tools will prove crucial in maintaining pathogen-free colonies in SIT programmes.

15. Following the successful suppression of target populations of *Aedes albopictus* in Guangzhou, China, through a combination of SIT and the incompatible insect technique, similar results were obtained in Singapore against *Aedes aegypti*, where the target population was significantly suppressed. In Cuba, an open field pilot trial using the SIT to suppress populations of *Aedes aegypti* resulted in a >90% reduction in mosquito population density.

16. The Centro Agricoltura Ambiente (CAA) in Italy and Moscamed Brasil in Brazil have been designated Agency Collaborating Centres since September 2017 and March 2018, respectively. The CAA was redesignated in May 2022 and Moscamed Brasil is in the process of redesignation. They have

reported significant development of the SIT package application for *Aedes albopictus* in Italy and *Aedes aegypti* in Brazil. Additionally, Sun Yat-sen University in China was designated as an Agency Collaborating Centre in 2021 to assist in the implementation of activities in the field for the development of the SIT for the control of mosquitoes over a period of four years.

17. The Agency continued to implement the coordinated research project (CRP) entitled “Mosquito Handling, Transport, Release and Male Trapping Methods”. The CRP resulted in novel protocols for monitoring, marking, handling, transport, and release of sterile males, targeting the control of *Aedes* species, which will be transferred to Member States and will benefit mosquito SIT pilot projects around the world. An ongoing CRP entitled “Mosquito Irradiation, Sterilization and Quality Control” was approved and began in July 2020. This CRP aims to develop protocols for mosquito irradiation and sterilization and quality control of mosquitoes.

18. In response to Member States’ needs for new sterile male mosquito release methods, the Agency, in collaboration with the European Research Council, has tested a light drone release system for sterile male mosquitoes in urban areas in France and Greece..



*FIG. B.3. Drone releasing sterile male mosquitoes (Aedes aegypti) on Réunion Island, France. (Source: IAEA)*

19. The Agency continued to provide Member States with support through five regional technical cooperation projects covering the Europe region, the Asia and the Pacific region, and the Latin America and the Caribbean region. It also provided support through an interregional technical cooperation project, which is a fundamental strategic platform for the exchange of knowledge and experiences worldwide.

20. The Agency continued to provide support to Member States through the technical cooperation programme in Bangladesh, Brazil, Cuba, Cyprus, Ecuador, Mauritius, Mexico, the Philippines, Portugal, South Africa, Sri Lanka, Sudan and Türkiye. The Agency has also supported pilot trials for mosquito SIT application in Italy, Spain and the United States of America. In the latter, the Agency provided technical advice to the Lee County Mosquito Control District on the development and implementation of an *Aedes aegypti* population suppression pilot SIT trial using an area-wide integrated pest management strategy. The pilot project is ongoing, and results obtained so far on Captiva Island show

a significant reduction of the wild mosquito population in the second semester of 2020 and complete suppression in 2021.

21. The Agency launched a phased conditional approach scheme, through which Member States can test and implement SIT for vector control with the objective to progress towards implementation of SIT field programmes.

22. As part of a Memorandum of Understanding between the Agency and the WHO, a Guidance Framework for Testing the Sterile Insect Technique as a Vector Control Tool against Aedes-Borne Diseases has been available to Agency Member States since April 2020. In addition, in August 2019, Agency and WHO experts assisted Bangladesh in assessing the country's dengue outbreak and developing a plan to test SIT to suppress the mosquitoes that spread the disease.

23. After a successful reduction in the prevalence of malaria since the beginning of the 21st century, the number of cases has remained stable in the past five years. The Agency is seeking further resources for the development of the SIT package against malaria-transmitting mosquitoes, particularly as it relates to the R&D component of the full SIT package, including its testing and validation, and transfer to Member States.

24. The SIT is part of an area-wide integrated vector management approach. The Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture and the IPCL have continued with the development, validation, and optimization of the SIT package as a complementary tool for the management of mosquito populations. Substantial progress has been made in collaboration with Member States, including through the technical cooperation programme, on two of the main challenges: the development of efficient sex separation methods that would allow male-only releases, and the aerial release of mosquitoes. The current developments in sexing and drone release will allow for the testing of the SIT approach in pilot trials to demonstrate that it is a safe, biosecure and responsible approach to managing mosquito populations.



# Strengthening the Support to Member States in Food and Agriculture

## A. Background

1. In resolution GC(62)/RES/9.A.5, the General Conference recognized the central role of agricultural development in accelerating progress towards several Sustainable Development Goals (SDGs), in particular to end hunger, achieve food security and improved nutrition, and promote sustainable agricultural development for the socio-economic benefits of all Member States. It consequently urged the Secretariat to further expand, in an integrated and holistic manner, its efforts to address, inter alia, food insecurity in Member States and to further increase its contribution to raising agricultural productivity and sustainability, reducing poverty and hunger, and improving farmers' incomes, through the development and integrated application of nuclear science and technology. It encouraged the Joint FAO/IAEA Division to continue responding to the major global trends framing agricultural development in order to ensure to the maximum extent possible an increased resilience of livelihoods to threats and crises in agriculture, including the adaptation to and mitigation of the effects of climate change.
2. The General Conference further recognized that the major global trends that will frame agricultural development over the medium term include rising food demand, lingering food insecurity, malnutrition, and the impact of climate change. It consequently urged the Secretariat to address the impacts of climate change on food and agriculture through the use of nuclear technologies, with priority on adaptation to and mitigation of the effects of climate change, including through the development of tools and technology packages. It invited the Secretariat to carry out activities for addressing climate change challenges under the thematic heading of 'climate-smart agriculture'.
3. The General Conference further invited the Secretariat, in view of the global trend in antimicrobial resistance (AMR) and its impact on human and animal health, to continue to follow international efforts to establish possible applications where nuclear/isotopic methods/tools may provide comparative advantages.
4. Welcoming the demand-driven research activities on the development of communication tools to improve decision-making in agricultural water management in Africa, and the new visualization platform for nuclear and radiological emergency preparedness and response for food and agriculture, the General Conference urged the Secretariat to further strengthen its effort to seek extrabudgetary funding for strengthening its research activities in the preparedness and response to nuclear and radiological emergencies affecting food and agriculture.
5. The General Conference, in resolution GC(65)/RES/11.A.8, requested the Director General to report on the progress made in the implementation of resolution GC(62)/RES/9.A.5 to the Board of Governors and to the General Conference at its sixty-sixth regular session.

## **B. Progress since the 62nd Regular Session of the General Conference**

6. The Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture (Joint FAO/IAEA Division), now named the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture (Joint FAO/IAEA Centre), currently oversees 35 coordinated research projects (CRPs) involving approximately 450 research institutions and experimental stations in Member States and is responsible for providing scientific and technical support to 328 national, regional and interregional technical cooperation (TC) projects. During the reporting period, 264 demand-driven workshops, seminars and training courses were held, with the participation of 6433 trainees from developing countries, mainly supported through the Agency's TC programme. In addition, the Joint FAO/IAEA Centre yielded 602 publications, including 124 technical documents, newsletters, guidelines and books; 290 articles in peer-reviewed scientific journals; 141 conference papers; and six special editions in peer-reviewed scientific journals.

7. Demand-driven research and development activities continued at the FAO/IAEA Agriculture and Biotechnology Laboratories in Seibersdorf, Austria, in response to Member States' requests, including the use of nuclear techniques for climate-smart agriculture and measuring agricultural greenhouse gases for better mitigation options; the development of isotopic and analytical techniques for food traceability and authenticity, as well as contaminant and residue analysis; the investigation of irradiated animal vaccines; the development of radiation hybrid maps for animal breeding; the strengthening of animal disease diagnostic applications for early detection of animal and zoonotic diseases, including COVID-19; the development of climate-adapted and higher-yielding crops; and the control of plant and livestock insect pests.

8. The International Symposium on Sustainable Animal Production and Health — Current Status and Way Forward, was held from 28 June to 2 July 2021. The main objectives of the symposium were to provide information and share knowledge on the application of modern and novel nuclear and nuclear-related techniques to support sustainable livestock production systems and to address issues that are limiting livestock productivity and causing animal diseases. The symposium was opened by the Directors General of the IAEA, the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health. The symposium was attended by nearly 3000 participants, in person and virtually, from around the world.



*FIG. B.1. Sharing knowledge on the application of modern and novel nuclear and related techniques to support sustainable livestock production systems was one of the main objectives of the International Symposium on Sustainable Animal Production and Health in July 2021. (Source: IAEA)*

9. The development and further enhancement of laboratory networks with the participation of multiple stakeholders continued to be a primary focus, in particular to strengthen support for the timely diagnosis, control and eradication of transboundary animal and zoonotic diseases (e.g. the Veterinary Diagnostic Laboratory (VETLAB) Network, network of ZODIAC National Laboratories); to enhance capabilities in food safety and food control systems (e.g. the Latin American and Caribbean Analytical Network (RALACA), the African Food Safety Network (AFoSaN) and the Food Safety Asia (FSA) Network); to foster crop improvement and adoption of modern biotechnologies (the Plant Mutation Breeding Network (MBN) for the Asia and Pacific region and the Coffee Mutation Network); and to share knowledge on the sterile insect technique (SIT) for insect pest control (Tephritid Workers Database).

10. The Agency continued to support capacity building, emergency interventions and South–South cooperation through the VETLAB Network, a scientific and technical network of national veterinary laboratories from 46 African and 19 Asian countries.

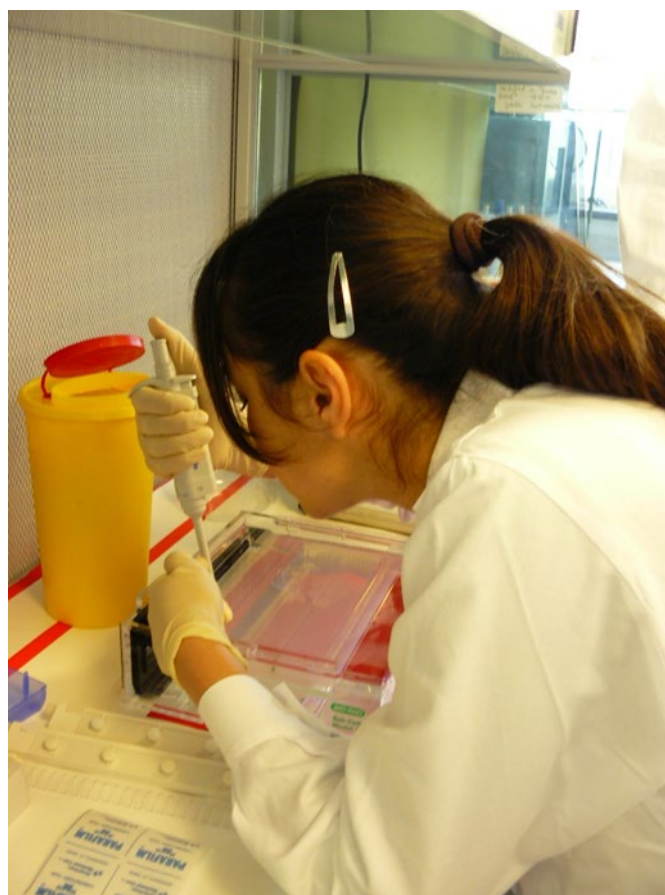
11. Capacities were strengthened to rapidly respond to outbreaks of African swine fever (ASF), equine and avian influenza, Ebola virus disease and Rift Valley fever.



*FIG. B.2. African swine fever is threatening Asia, Europe, and the Americas.  
(Source: IAEA)*

12. The Indonesian Research Center for Veterinary Sciences was the first to rapidly detect the ASF virus. Since the emergence of ASF in Indonesia in September 2019, the institute has implemented diagnostic tests for disease confirmation and surveillance. These include ASF-specific and multiplex (haemorrhagic disease panel) RT-PCR and virus isolation in primary cell cultures.

13. Since 2019, several Asian countries have experienced the emergence of lumpy skin disease (LSD) virus, which spread rapidly during the summer of 2020 in Bangladesh, Bhutan, Indonesia, Myanmar, Nepal, Sri Lanka, Thailand, and Viet Nam. The Agency, through the VETLAB Network, supported these countries with laboratory material and molecular characterization of local LSD virus isolates, sequencing the full genome or targeted multiple genes for Bangladesh and Viet Nam.



*FIG. B.3. Trainee in Seibersdorf Laboratory as part of the capacity building programme of the VETLAB Network. (Source: IAEA)*

14. Senegal detected and notified rabbit haemorrhagic disease virus (RHDV2) for the first time in 2020. It soon spread to Burkina Faso and Nigeria, causing high mortality in domestic rabbits. The Agency, through the VETLAB Network supported laboratories in West Africa in responding to these outbreaks.

15. Episodes of acute mortalities or severe diseases owing to apparent unknown reasons can occur in wild and domestic animals. Episodes of large mortalities have been reported in Burkina Faso (in wild birds such as doves) as well as in Ethiopia and Kenya (in camels). The Agency, through the VETLAB Network, is supporting laboratory investigations to assess whether known or unknown infectious agents are present and to reveal the reason for these episodes.

16. Novel irradiated prototype vaccines were tested to investigate their efficacy against animal diseases. Experiments were done in collaboration with the University of Veterinary Medicine Vienna, the Austrian Agency for Health and Food Safety (AGES) and the Experimental Zooprophyllactic Institute of Venice. Several experiments conducted in Seibersdorf and in 11 Member States are providing proof-of-concept for the use of irradiation to produce bacterial and viral vaccine antigens. Technical support was provided to establish a flow cytometry facility at the University of Peradeniya in Sri Lanka, an indispensable tool for evaluating vaccine response.

17. A whole genome sequencing technology, based on the Oxford Nanopore MinION platforms, was implemented in seven African veterinary laboratories in the Democratic Republic of the Congo, Ethiopia, Morocco, Namibia, the Niger, and Senegal, through the TC programme. The technology will



be used primarily in a metagenomic mode to enable detection of unknown pathogens in domestic and wildlife carriers.

18. In 2020, the Agency, in collaboration with the University of Veterinary Medicine Vienna and the International Camel Consortium for Genetic Improvement and Conservation, developed a multi-species camelid deoxyribonucleic acid (DNA) chip for selection and breeding of high producing camels. This chip contains around 200 000 markers and can be used for genetic evaluation of a variety of camel species, including dromedaries, Bactrian camels, alpacas and llamas. The chip is currently under validation and field testing and will be rolled out in 2022.

19. The Agency provided technical support to six countries — Argentina, Bangladesh, Peru, Serbia, Sri Lanka, and Uruguay — in performing genome-wide evaluation of their local cattle. Bovine DNA chips consisting of 60 000 markers were used to genotype more than 3500 cattle from these countries. The DNA chip-based screening significantly improved the capacities of the national cattle breeding programmes of these countries for identifying animals with considerable genetic potential for increased milk productivity.

20. The Agency supported Member States in enhancing utilization of local feed resources for sustainable livestock production. Efforts continued in 15 countries (Argentina, Benin, Brazil, Burkina Faso, Burundi, Chile, China, Egypt, Eritrea, Ethiopia, India, Indonesia, Pakistan, Senegal and South Africa) to evaluate and implement animal nutrition and feeding strategies to improve livestock feed efficiency and reduce livestock greenhouse gas emission intensities.

21. The Agency continued its efforts to improve the laboratory capacities of Member States for implementing advanced DNA-based technologies for efficient management of locally available animal genetic resources. Through TC projects, animal genetic laboratories were set up or strengthened in 17 countries (Burkina Faso, Cambodia, Cameroon, Côte d'Ivoire, the Dominican Republic, Eritrea, Indonesia, Kenya, Mongolia, Nigeria, Paraguay, Senegal, South Africa, Sri Lanka, Togo, the United Republic of Tanzania and Zimbabwe) to enhance their capabilities in applying modern biotechnologies for animal breeding and improvement. Research was supported through CRPs in ten countries (Argentina, Bangladesh, Burkina Faso, China, India, Kenya, Pakistan, Peru, South Africa and Sri Lanka) for practical applications of nuclear and related genomic information to improve the efficiency of national livestock breeding programmes.

22. Under the Agency's coordinated research programme, field trials were conducted to quantify animal feed intake and optimize diet selection for cattle grazing in heterogeneous pastures using compound-specific stable isotopes in ten Member States in Africa, Asia and Latin America.

23. An Agency publication entitled *Strategies and Practices in the Remediation of Radioactive Contamination in Agriculture* was issued in February 2020. A book entitled "Nuclear and Radiological Emergencies in Animal Production Systems, Preparedness, Response and Recovery" was published in 2021. It covers important aspects of the preparedness, response and recovery before, during and after nuclear or radiological emergencies in animal production systems.

24. RALACA has expanded to include 57 institutions in 21 countries, as well as coordinating workshops and interlaboratory trials and training. AfoSaN has continued to grow and reached 102 laboratories, and research and food control organizations have been established in 39 participating countries, fostering technical networking and capacity building. The FSA Network, comprising 46 institutions in 29 countries, is facilitating collaboration among its member institutions in improving laboratory testing capabilities (e.g., Pakistan supported Papua New Guinea in food hazard testing, Lebanon assisted Jordan in testing pesticide residues, and Thailand supported Cambodia and Myanmar in testing contaminants), contributing to laboratory excellence and accreditation.

25. The MBN for the Asia and Pacific region, formally established with 13 signatory Member States at its first workshop in July 2019, continues to operate as a pilot network in the Asia and the Pacific region, with strong interest for a global network growing in the Latin America region. The MBN's key roles as identified in the 'Jingzhou Proposal' of July 2019 are: strengthening national and regional capacities; enhancing germplasm resources; enabling the use of speed-breeding technologies; establishing functional genomics platforms; establishing stress-screening locations; early detection of transboundary pests and diseases; conservation of mutant germplasm; and joint resource mobilization.

26. The Agency responded to the request for support to combat the banana Fusarium wilt tropical race 4 (TR4) in the Andean region by organizing an expert mission to Peru that brought together researchers from the region and provided urgent capacity building for disease detection, disease surveillance and plant breeding. The first meeting under the new interregional TC project on detection, genetic resistance and integrated management of TR4 that includes 12 Member States from the Latin America region was held in Ecuador in February 2022. The Agency also organized a two-day global research symposium on banana fusarium wilt TR4 in Quito, at which key global researchers and other stakeholders discussed their efforts to combat the disease.

27. A recently completed CRP has led to the development and release by partners in China of a new mutant variety of Cavendish, a type of banana commonly used for export, with resistance to TR4. Other Member States have identified putative mutants with possible resistance or tolerance to the disease.



*FIG. B.4. Training course on banana tissue culture, mutagenesis and screening for TR4 resistance at the Joint FAO/IAEA Laboratories in Seibersdorf in February 2022. (Source: IAEA)*

28. In 2021, the Agency, through the Joint FAO/IAEA Centre, held an awards ceremony to recognize achievements in plant mutation breeding and associated biotechnologies. Awards were presented during a side event at the 65th regular session of the Agency's General Conference. The ceremony recognized 28 recipient individuals, groups or institutions across 11 "Outstanding Achievement Awards", 10 "Women in Plant Mutation Breeding Awards" and 7 "Young Scientist Awards".

29. The Agency signed an agreement with the La Molina National Agricultural University, Peru, recognizing it as a new Collaborating Centre for plant mutation breeding and associated biotechnologies. This four-year Collaborating Centre agreement was signed at a side event during the 65th regular session of the General Conference. Immediately after signing the agreement, the Collaborating Centre hosted a regional expert mission on banana Fusarium wilt, bringing together experts from four countries for discussion of the topic.

30. The Agency developed, in close collaboration with the FAO, guidelines on the use of nuclear and isotopic techniques for tracing antimicrobial movement from agricultural areas to the environment. Work is under way to produce a detailed guidance document for testing the methodology in Member States.

31. Applied research in parallel with capacity building on methodology for food authentication and detection of adulterants led to enhanced capacities for food safety and quality control in more than 30 Member States. This included various food products, such as milk, honey and tea in China; high-value edible bird's nests in Malaysia; truffles in Slovenia; vinegar in the Philippines; and imported pork and milk products in Singapore. A 'quality assured' mark was also developed for local milk and dairy products in Slovenia.

32. Agency support resulted in ISO 17025:2017 accreditation for Member State food safety laboratories in Botswana, Mongolia, Namibia, Nigeria, Pakistan, South Africa and Uganda. This increases the reliability of testing and monitoring chemical residues and related contaminants in foods.

33. Nuclear and isotopic techniques developed through CRPs were applied in national surveillance and monitoring programmes for multiple/mixed residues and contaminants for more than five foodstuffs in ten Member States. One example is the multi-residue analytical method for detection of 132 compounds, including pesticides and mycotoxins, in quinoa to address the challenge of quinoa export rejections in Peru. Radioreceptor screening tests were implemented in Burundi, Côte d'Ivoire, Georgia, Lesotho and Myanmar to detect pesticide and veterinary drug residues, including antimicrobials.

34. The Agency continued work relevant to AMR, including development of an isotopic multi-residue method for quantification and confirmation of antimicrobial residues and mycotoxins in animal waste. This built on earlier work on determination of chlortetracycline antimicrobial residues, antimicrobial activity and presence of resistance genes in droppings of experimentally treated broiler chickens and is critical to global AMR efforts. The Agency also supported more than 30 Member States in their antimicrobial residue testing and monitoring, a critical component of AMR. In 2021, the Agency initiated a CRP entitled "Isotopic Techniques to Assess the Fate of Antimicrobials and Implications for Antimicrobial Resistance in Agricultural Systems", to apply a combination of isotopic and bioanalytical/molecular methods to different agricultural systems to assess the fate and dynamics of antimicrobials and implications for AMR.

35. The Agency continued to support the Codex Alimentarius Commission and the establishment of food safety standards and guidelines through active participation in the Codex Committees on residues of veterinary drugs in food, pesticide residues and contaminants in food, and methods of analysis and sampling. Capacity building and technology transfer capabilities are enabling many Member States to implement Codex standards, guidelines and codes of practice.





*FIG. B.5. Sample preparation for analysis of organic strawberries.  
(Source: IAEA)*

36. The Agency, through the Joint FAO/IAEA Centre, supported the establishment or strengthening of five food safety and environmental health laboratories in Eritrea and The Gambia, as well as the development of a blueprint for antimicrobial residue monitoring in the Asia and the Pacific region (in collaboration with the FAO Regional Office for Asia and the Pacific), piloted in Singapore and Thailand. Within the framework of the African Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (AFRA), two AFRA regional designated centres were recognized in Algeria and Nigeria to support food safety education and analytical services, with a view to contributing to the enhancement of Africa's public health and regional and international trade in foodstuff through laboratory networking.

37. A CRP on the development of radio-analytical techniques for the control of chemical residues in aquaculture was completed in 2021. The project involved institutes in 16 countries and resulted in the development of 36 analytical methods and 19 papers or scientific reports. The methods have been applied in national residue monitoring programmes in at least eight countries. The research supported 17 postgraduate fellows and contributed to enhanced laboratory competence, for example through ISO 17025 accreditation of laboratories in Nigeria, South Africa and Uganda.

38. In 2021, a five-year Agency effort to stimulate the development of electron beam and X-ray irradiation of food was completed. Results included the development of new low energy beam applications using machine generated ionizing radiation, new beam technology, software and modelling studies to aid more efficient dose validation work and enhance productivity, and improved dosimetry for low energy X-ray irradiation. Low energy beam research may provide technology that is less expensive and more amenable to being used in food businesses.

39. The Agency provided support to Mediterranean fruit fly control in Ecuador, as a component of the National Fruit Fly Management Project. As a result of the Agency's support, fruit and vegetable quality and quantity were increased, and international trade facilitated, with farmers being able to start the export of golden berries, dragon fruit and tomatoes to markets in the United States of America, Latin America and Europe.

40. The Agency provided support to Argentina in plant insect pest control, which is now bearing fruit thanks to the successful application of the SIT against the Mediterranean fruit fly. In early 2020, China recognized the fruit fly free status of Patagonia and parts of Mendoza Province. As a result, cherries and

other stone and pome fruits from these regions of Argentina can be exported to the world's largest fresh food markets.

41. The Agency assisted the Mexican state of Colima in avoiding significant economic damage from an outbreak of the Mediterranean fruit fly. Responding to a request for support from the Mexican Government, the Agency assisted national plant protection authorities in Colima in bringing the outbreak to an end. Assistance included developing and providing guidance for the execution of an emergency action plan using a nuclear technique. The Colima operation is on track and, for now, the outbreak is well under control, and the livelihoods of farmers remain safe from this devastating pest. A new sterile Mediterranean fruit fly mass-rearing facility was recently inaugurated by the Mexican President in Metapa de Domínguez, Chiapas, Mexico. The facility uses the most advanced fruit fly production and sterilization techniques. It is the world's second largest fruit fly facility, with a capacity to produce one billion sterile males per week. The goal of the facility is to consolidate the current containment barrier at Mexico's border with Guatemala, and to eliminate Mediterranean fruit fly gradually from Guatemala, in line with the Moscamed Programme's long-term objectives. The facility will be instrumental in keeping Guatemala free of this invasive pest, and in protecting and supporting sustained production and trade of fruit and vegetable commodities.



*FIG. B.6. A release box containing some 15 million sterile male fruit flies being loaded to a Cessna aircraft for release over Colima, Mexico. (Source: DGSV SENASICA)*

42. The second edition of the book “Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management” was published in 2021. The 1200-page volume takes a generic, thematic, comprehensive and global approach in describing the principles and practice of the SIT. All aspects of the SIT were updated and the content considerably expanded compared to the first edition. This second edition covers the latest developments in the technology, including on managing pathogens in insect mass rearing; using symbionts and modern molecular technologies in support of the SIT; applying post-factory nutritional, hormonal and semiochemical treatments; applying the SIT to eradicate outbreaks of invasive pests; and using the SIT against mosquito disease vectors.

43. The book “Area-Wide Integrated Pest Management: Development and Field Application” was also published in 2021. The 1012-page volume deals with all aspects of the application of AW-IPM approaches that aim at the management of total pest populations, involving a coordinated effort over often larger areas. For major livestock pests, vectors of human diseases and pests of high value crops

with low pest tolerance, there are compelling economic reasons for implementing AW-IPM programmes.

44. The use of the SIT to prevent reintroduction of the Mediterranean fruit fly was expanded to pest free areas in Patagonia and Mendoza, Argentina, as well as in Chile. Both countries are adopting a preventive release strategy such as the one in place in California and Florida, United States of America, since 1994.

45. The Agency provided support to the Plurinational State of Bolivia to build a state-of-the-art fly emergence and release facility to support SIT implementation. Three million sterile male Mediterranean fruit flies are being shipped weekly from a mass-rearing and sterilization facility located in Mendoza, Argentina. The sterile flies are released over 2000 hectares where the pest is present in Cochabamba, Plurinational State of Bolivia.

46. The Agency recently developed the SIT package for the spotted wing drosophila and European grapevine moth, pests of soft fruits and grapes, respectively. Pilot field trials for both species, in collaboration with Argentina and Chile, were initiated in 2020.

47. During the reporting period, the Agency published 28 standard operating procedures, manuals and guidelines on AW-IPM for the benefit of national plant protection and animal and human health organizations, covering fruit flies, mosquitoes and trypanosome species. An animated infographic entitled “Fruit Fly Standards can Help Gain Market Access” was produced in collaboration with the International Plant Protection Convention.

48. The Agency continued to provide technical support to Senegal in its efforts to create a tsetse-free zone in the highly productive agricultural region of Niayes in western Senegal, using an AW-IPM approach with an SIT component. The tsetse fly populations have been eliminated in 99% of the project area, and transmission of tsetse-borne trypanosomiasis has stopped, allowing Senegal to continue importing more productive cattle into the area.

49. The Agency continued to provide technical assistance in plant mutation breeding and associated biotechnologies to more than 70 Member States and supported the development and release of 36 new and improved crop varieties during 2021 in 8 Member States. These include Bangladesh (cotton, lentil and rice), China (wheat), Cuba (soybean and tomato), India (rice), Indonesia (rice and soybean), Pakistan (chickpea, cotton, mung bean and rice), Thailand (mung bean), and Yemen (barley, sesame and wheat). During 2021, the Agency also received and responded to 33 requests for seed/plant irradiation for mutation breeding from 22 Member States across 24 different plant species covering a total of 297 accessions/varieties.

50. The Agency continued to assist Member States in tackling Striga, a serious parasite for cereal and cowpea crops in sub-Saharan Africa. This parasitic weed causes yield reduction of staple crops such as maize, millet, rice and sorghum, resulting in enormous economic losses. Burkina Faso, Madagascar and Sudan have developed maize, rice and sorghum mutant lines with resistance to Striga.

51. Technical guidance from the Agency to Pakistan in mutation breeding and associated biotechnologies over the past four years has enabled the development and increased seed dissemination of four new and improved mutant cotton varieties resulting in a continuously expanding cultivation area. The area in which the four recent mutant cotton varieties are found continues to grow, and constitutes over 40% of the total cotton area in the Punjab province, the major cotton-growing region in the country. The Agency is also providing technical support to Azerbaijan in improved soil, nutrient and water management practices, which has helped increased cotton production.

52. The Agency strengthened its cooperation with small island developing States in the area of crop improvement for food security. Through the TC programme, the second phase of the first mutation

breeding project for the region was launched for improving crop resilience to climate change. The project aims to improve the main crops of the Pacific Islands (taro, sweet potato, banana and chili). The first coordination meeting was held in November 2021, with the participation of scientists from Fiji, the Marshall Islands, Palau, Papua New Guinea and Vanuatu.

53. The Agency continued its support to more than 40 African, Asian, European and Latin American Member States in managing agricultural water for enhancing crop water productivity through the use of the cosmic ray neutron sensor. This technology bridges the gap between remote sensing and point measurement of surface water to help farmers improve irrigation management, ensure sustainable agricultural production and mitigate the impacts of climate change.

54. The Agency has furthered the development of the online Decision Support System for Nuclear Emergencies Affecting Food and Agriculture. The system is being customized for Member States such as Belgium and China to provide tailor-made solutions for improving nuclear emergency preparedness and response in food and agriculture. It includes the collection, management and visualization of appropriate data from affected areas with the help of machine-learning modelling tools to ensure timely dissemination and communication to stakeholders and the general public.

55. The Agency, through the TC programme, assisted 20 African countries in improving land and water management practices and enhancing their resilience in farming systems under changing climatic conditions using advanced nuclear and modern digital technology to address the challenges posed by climate change and to make progress towards reaching the African targets for food security. The Agency also contributed to the use of digital agriculture as part of demand-driven research activities on communication tools to improve decision making in agricultural water management for Member States. It has developed real-time digital technology for mapping soil properties and monitoring landscape water availability, along with a new visualization platform for real-time monitoring.

56. The Agency coordinated international research and development activities using isotopic techniques to identify greenhouse gas emission pathways and, in turn, devise effective mitigation techniques. Among the achievements were the development of a novel instrument for real-time measurement and analysis of carbon dioxide in agriculture and the development of a low-cost and robust method for methane measurement, in collaboration with the Agrobiological Centre of the Brazilian Agricultural Research Corporation and the Agronomic Institute of Paraná.

57. The Agency organized, in collaboration with the FAO, the International Symposium on Managing Land and Water for Climate-Smart Agriculture in July 2022, aimed at facilitating the exchange of information and knowledge among soil, water and environment professionals from developed and developing countries to advance the understanding of collaboration on and capabilities to respond to the impact of climate change and the rapidly changing global environment.



*FIG. B.7. The Agency organized, in collaboration with the FAO, the International Symposium on Managing Land and Water for Climate-Smart Agriculture in July 2022. (Source: IAEA)*

## C. Strengthening the FAO–Agency Partnership

58. The Joint FAO/IAEA Centre has continuously adjusted its programmatic activities to address the evolving needs of Member States and to help them improve productivity and address threats to food and agriculture production, livelihoods and health, as well as to accelerate delivery of the SDGs.

59. The Directors General of the IAEA and the FAO signed a Revised Arrangement for the FAO–IAEA partnership on 23 February 2021, renaming the Joint FAO/IAEA Division as the Joint FAO/IAEA Centre and expanding the horizons of their cooperative work. Both organizations have committed to strengthening the FAO–IAEA strategic partnership for the benefit of millions of people.

60. The Revised Arrangement has expanded the areas of common interest to include the “improvement of monitoring and controlling of transboundary animal, zoonotic and plant diseases” as a key area. This change formally recognizes the collaboration that was taking place and will enable the integration of the Joint FAO/IAEA Centre laboratories’ capacities into FAO’s work on One Health. The strengthened partnership will contribute to the Agency’s Zoonotic Disease Integrated Action (ZODIAC) project.

61. The Agency has enhanced its work with the FAO on important global initiatives, such as the Global Strategy for the Control and Eradication of Peste des Petits Ruminants; the collection and preservation of genetic material of livestock available locally in Member States for the identification of DNA markers associated with high productivity and disease resistance; the Global Soil Laboratory Network, within the Global Soil Partnership; and the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture through demand-based innovations that focus on the improvement and use of plant genetic diversity.



# Use of Isotope Hydrology for Water Resources Management

## A. Background

1. At its 63rd regular session in September 2019, the General Conference, through resolution GC(63)/RES/10, requested the Secretariat, subject to the availability of resources, to further strengthen efforts to fully exploit the potential of nuclear and isotopic techniques for water resources development and management in interested countries; to continue to help Member States obtain easy access to isotopic analysis by upgrading selected laboratories; to expand activities related to the IAEA Water Availability Enhancement (IWAVE) Project and to groundwater management; to provide easier access for Member States to new techniques for the use of noble gas isotopes in the age-dating of groundwater; to strengthen activities which contribute to the understanding of climate and its impact on the water cycle; to expand the use of geochemical and isotope tools to enhance hydrological models in mining areas; to expand the use of isotopes for pollution studies and to carry out international intercomparison exercises; to further strengthen efforts to enhance the temporal and spatial coverage of the Agency's global isotope monitoring programmes for precipitation and rivers; and to continue to develop human resources in isotope hydrology.

2. The General Conference, in resolution GC(65)/RES/11.A.5, requested the Director General to report on the progress made in the implementation of resolution GC(63)/RES/10.A.3 to the Board of Governors and to the General Conference at its sixty-sixth regular session.

## B. Progress since the 63rd Regular Session of the General Conference

### B.1. Strengthening Isotope Hydrology Activities

#### B.1.1. Isotope Hydrology Laboratories

3. The development of a new state-of-the-art helium-3 mass spectrometer system for the analysis of tritium concentrations using the helium-3 ingrowth method and applicable to various forms of environmental samples was completed in the Agency's Isotope Hydrology Laboratory (IHL) in the first half of 2020. The mass spectrometer was procured using Peaceful Uses Initiative funds provided by Japan. The helium-3 ingrowth method is non-destructive and much more sensitive than other analytical techniques. A standard operating procedure was developed, and the system is now ready for wider applications through coordinated research projects (CRPs) and technical cooperation (TC) projects to better assess tritium levels in natural environmental materials.





*FIG. B.1. New method for tritium enrichment based on solid polymer electrolyte membrane (PEM) technology, with distillation system in background. (Source: IAEA)*

4. Isotope fingerprinting of nitrate is critical in allowing isotope hydrologists to identify and distinguish sources of nitrate in aquatic systems and to quantify natural remediation processes like denitrification and nutrient assimilation in rivers. In 2020, the Agency published a new low-cost titanium (III) chloride reduction method for the rapid conversion of aqueous nitrate to nitrous oxide gas, which is required to undertake isotope measurements. The new method lowers the effort and cost of previous methods by 90% and has been adopted for routine use in the IHL in support of CRPs and TC projects related to the impacts of nutrient pollution on water quality in 2021-2022. Over 400 samples have so far been received from eight Member States.

5. The installation of a new ion chromatography (IC) system with capacity for simultaneous analysis of cations and anions was completed in 2021. The IC system allows for the measuring of major and trace cations and anions, including nitrate, nitrite and ammonium, and will assist programmatic activities pertaining to isotope monitoring in precipitation, groundwater pollution studies and the operation of global isotope monitoring networks, as well as the CRPs that support nitrogen pollution, water quality and climate change studies requiring the assessment of nitrogen oxides and sulphur oxides. The experience gained from operating the IC system will allow the Agency to provide advice and technical assistance to Member States supported through TC projects.

6. The Agency acquired an elemental analyser isotope ratio mass spectrometer (EA-IRMS) system to measure sulphur stable isotopes (namely the ratio of sulphur-32 to sulphur-34) in ground and surface waters. Sulphur isotopes are used to assess acid mine drainage, seawater intrusion and other important



water quality indicators. The EA-IRMS system was installed in 2021 and is being used to support several CRPs on water quality and the impacts of mining on the local water cycle during 2022.



*FIG. B.2. The new state-of-the-art helium-3 mass spectrometer system for the analysis of tritium concentrations using the helium-3 ingrowth method installed in the Isotope Hydrology Laboratory.  
(Source: IAEA)*

7. The Agency continued to develop low-cost, easy-to-operate tritium enrichment units (TEUs) based on solid polymer electrolyte membrane technologies. The TEUs are used to conduct simpler and more precise tritium measurements in groundwater and precipitation samples. Expanded analytical facilities for tritium in natural waters are required for the assessment of groundwater replenishment rates and to facilitate groundwater vulnerability mapping for Member States.

8. A specialized laser spectrometer for the precise quantification of the rare oxygen-17 isotope in water samples is now fully operational at the Agency's IHL. Oxygen-17 is a new tracer in hydro-climatological applications that offers insights into important climatically driven hydrologic processes such as evaporation or the distinguishing of stratospheric water sources. The new laser is currently being used to support the Agency–World Meteorological Organization (WMO) Global Network of Isotopes in Precipitation (GNIP) programme.

9. In 2021, the IHL submitted plans to substantially increase its footprint and to enhance the analytical services and support it can offer Member States with building works scheduled to start in late 2022. The enhancement will include the development of a dedicated cleanroom and include an inductively coupled plasma mass spectrometry instrument for analysing trace metals, as well as several other radionuclides and isotope tracers important for tracking the movement of groundwater through different aquifers. The

enhancement of the IHL will also improve workflows through re-organization of workstreams that will allow improved turnaround times for Member States using the IHL facilities.

### **B.1.2. General**

10. Thirty-one isotope hydrology laboratories were equipped with or upgraded their laser spectrometry analysers in the period 2019–2022 through the Agency’s TC programme. Since the laser technology for stable isotope analysis became available 12 years ago, a total of 105 laboratories in 69 Member States have benefited from the Agency’s support to acquire and operate laser spectroscopy instruments used to measure stable oxygen and hydrogen isotopes in water samples. In addition, the Agency provided four TEUs designed and developed by the Agency to four Member States during the reporting period.

11. The Agency published the results of the Tritium Intercomparison in 2020. A record number of 78 laboratories worldwide participated in the test. The results showed that approximately 75% of the laboratories produced reliable isotope data suitable for use in water resource investigations; however, around 25% underperformed owing to systemic errors, mistakes and poorly performing instrumentation. Several strategies to improve and correct analytical problems were recommended, such as the use of new data evaluation strategies and screening runs for contamination, as well as the inclusion of additional control standards.

12. Results of the first proficiency test to assess the isotope ratio mass spectrometry and laser absorption spectroscopy measurements of 25 laboratories in Latin America and the Caribbean were published in 2020. Eighty-one per cent of the laboratories had satisfactory performance for deuterium (hydrogen-2), but only 54% achieved similar scores for oxygen-18. The strict conditions of the proficiency test allowed identification of core challenges in laser absorption spectroscopy and the provision of recommendations to improve the performance of a number of laboratories reporting analytical problems.

13. The Water Isotope Interlaboratory Comparison 2020 proficiency test for water stable isotopes (such as oxygen-18 and hydrogen-2) was conducted on five natural test waters, and for the first time included the rare oxygen-17 isotope, which has recently begun being used in climatic studies, with a record number of 307 laboratories from 88 Member States, including strong participation from African, Asian, and Latin American and Caribbean Member States. Despite delays and laboratory closures due to the COVID-19 pandemic, 281 laboratories still completed the proficiency test on time. Results showed that 85% of laboratories were able to produce accurate results, with the remaining 15% showing less adequate results. The quality of the latter group’s results may be attributed to reasons such as inexperience, poor handling of reference materials and general instrumental performance issues. The Agency will work with these laboratories to assist them in improving their results. The results of the oxygen-17 intercomparison highlighted the substantial challenges in attaining the desired precision and accuracy required to incorporate this rare isotope into climate studies. The Agency will continue to provide assistance to laboratories working with this isotope to overcome the identified challenges.

14. The Fukushima Prefecture Initiative Project aimed at the development of simple and rapid analysis methods for radionuclides was completed in 2021. The Agency has actively supported Fukushima Prefecture in setting up its own analytical facility in its prefectural laboratory over the past four years. The project resulted in Fukushima Prefecture being able to analyse tritium and strontium-90 in environmental samples precisely and accurately according to the system and analysis protocols developed and validated jointly with the Agency.

15. The CRP entitled “Use of Isotope Hydrology to Characterize Groundwater Systems in the Vicinity of Nuclear Power Plants” was completed in 2020. Ten teams, from Argentina, Brazil, China, Italy, Japan, Lithuania, Morocco, Pakistan, Ukraine and Viet Nam, used stable and radioactive isotopes to characterize groundwater flow systems around several nuclear power plants in a comprehensive manner

to plan and implement countermeasures in the event of a radioactive leak or accident. Several scientific papers describing the results and recommendations of the studies carried out in the CRP were published in 2020.

## **B.2. The IWAVE Approach**

16. The introduction of the IWAVE process in the past two TC cycles has shown the relevance of IWAVE consultations and workshops in the design, as well as the various stages of implementation, of TC projects dealing with the use of isotope hydrology tools. The IWAVE approach is now considered an essential tool to efficiently coordinate the Agency's and Member States' efforts in the planning and formulation of TC projects to ensure that key hydrological gaps are properly addressed and that relevant stakeholders actively participate in these projects from the early stages. IWAVE particularly helps to develop a long-term strategy for technical collaboration, resulting in more successful project outcomes with greater impact and sustainability.

17. During the period 2019–2022, IWAVE workshops and expert missions were carried out in the context of regional and national TC projects in Africa (Benin, Cameroon, Eswatini, Ghana, Kenya, Mali, Mauritania, the Niger, Nigeria, Senegal and Togo) and the Latin America and the Caribbean region (Bolivia, Colombia, Mexico and Paraguay). Groundwater resource assessments were conducted in five transboundary aquifers in the arid and semiarid regions of the Sahel, the Guarani aquifer in South America, the Dry Corridor in Central America, and deep aquifers in Mexico. In addition, the information gathered as part of the IWAVE approach helped to better assist Member States in strengthening their technical capabilities and, in particular, their laboratory infrastructures. IWAVE has fostered closer interaction between various water sector stakeholders, including hydrologists, modellers, managers and policy makers, contributing to more confident water resources assessments.

## **B.3. Water Quality**

18. The CRP entitled “Isotopes to Study Nitrogen Pollution and Eutrophication of Rivers and Lakes” was finally concluded in July 2022 after some pandemic-related delays. The project, which included 18 Member States from five continents, facilitated a better understanding of nitrogen dynamics in water resources and improved expertise in utilizing nitrate isotopes (nitrogen-15 and oxygen-18) to evaluate the origin of nitrate pollution and assess related analytical methods and interpretations. The CRP succeeded in conducting the first measurements of nitrate isotopes in river waters in seven Member States (Argentina, Chile, Cuba, Ghana, India, Malaysia and Sri Lanka). Three new laboratories in China, Cuba and India were set up for nitrate isotope analysis of water samples during the project, and several other Member States have received assistance to establish similar facilities. Around 500 water samples from 13 participating Member States were analysed for nitrate isotopes at the Agency's IHL. More than 20 new case studies related to the application of nitrate isotopes in surface waters and groundwaters have been published so far.

19. A global database on nitrate isotopes (nitrogen-15 and oxygen-18) composed of more than 5000 entries from 45 Member States covering the past 25 years was compiled and made available on the Agency's website. Analysis of the database revealed that shallow aquifers suffer from higher nitrate concentration levels than rivers, originating mostly from fertilizers, and urban and animal waste. The analysis also showed that, regardless of the source of nitrogen pollution, environmental factors such as temperature, climate and season strongly affect the processes that nitrogen species undergo from the moment they are introduced into aquatic systems. These findings thus have serious implications for the management of pollution in waterways.

20. Building on the work of the concluded CRP, a new CRP entitled “Improving Understanding of Nitrate Sources in Connected River and Groundwater Systems Through Linking Nitrate Isotopes and



Contaminants of Emerging Concern” was initiated in 2022. Water quality has been identified as a high priority for nearly all Member States with projects under Programme 2.3 (“Water Resources”), and the new CRP is specifically designed to assist Member States in improving their ability to address water quality issues. The CRP will focus in more detail on how nitrate isotopes in combination with specific contaminants of emerging concern can help Member States manage water quality concerns through analysis and identification of nitrate pollution sources. A total of 12 institutions from 12 Member States will participate in the CRP.



*FIG. B.3. Sampling water quality in Tajikistan. Retreating glaciers and reductions in melt water will impact groundwater water quality due to changes in water temperature (Source: IAEA)*

## **B.4. Climate and Water Resources**

21. Re-analysis of the 60-year record of oxygen-18 in precipitation worldwide revealed complex temporal and spatial climatic isotope responses (e.g. warming and cooling in both directions over time). Advanced supervised machine learning tools were applied to detect trends and patterns over decades. Large decadal scale cyclical events, such as the Atlantic Multidecadal and Pacific Decadal Oscillations, were found to be the biggest drivers of oxygen-18 variation and climate on the Earth’s continents. In contrast, oceanic islands seem to be better positioned as indicators of long-term climatic isotope responses as they experience fewer interfering impacts from the oscillations than the continents. These results have been published and made available to Member States together with recommendations on the relevance of GNIP and isotope measurements in precipitation to climate change studies.

22. As part of ongoing efforts to better characterize and map present and future water availability and quality in the Sahel region, a dedicated isotope database containing isotope and hydrochemical data was compiled by the Agency. This unique database contains isotope and water quality data obtained as part of the work done under several TC projects in 13 Member States from the late 1960s until today. Besides data used to map water quality in the region, this resource contains stable isotope data, carbon-14 data

and more than 3000 tritium records. This naturally occurring radioactive isotope of hydrogen is being used to date groundwater to as far back as 100 years ago. This critical piece of information is being used to develop hydrological maps at various spatial scales showing areas containing groundwater being replenished under current semiarid conditions, and those where fossil groundwater is the most common source of water. Situated in a critically sensitive climatic zone, and with a huge demand for additional water resources, the Sahel region and its future rely on precise information on the renewal rate of these valuable water resources.

23. A global database of isotope data for lakes was compiled to estimate lake vulnerability to evaporation, a vulnerability that can be intensified by flow regulation and over-exploitation particularly in response to climate change. The dataset comprises 7415 stable isotope measurements from 1256 lakes of all sizes worldwide spanning diverse geographical and climatic zones: tropical, arid, temperate, continental and polar. Each lake was evaluated and modelled for its evaporation losses using an array of potential drivers of lake-catchment evaporation obtained from global geospatial datasets. The database will be open access for Member States and can be used to characterize hydrological cycles and better predict the responses of lakes to climatic variability and changes to the ecosystem.

24. To better understand the impacts of climate change on water resources, a new CRP on isotopic assessment of the impacts of climatic and hydrological changes on wetland–groundwater ecosystem interactions was initiated in 2022. The goal of the CRP is to help Member States understand the linkages between groundwater systems that act as a buffer against climate variability and wetlands that present a more visual impact of climate change. Since the two systems are not independent, understanding hydrological changes in wetland systems provides a window into the linked groundwater systems and enables the creation of better management strategies for the long-term protection of wetlands, as well as the sustainability of groundwater systems that support agricultural and domestic water supplies. Wetland loss and the associated biodiversity losses have been identified as a serious concern in many Member States and have been highlighted under Sustainable Development Goal indicator 6.6.1, which shows that 21% of world's water basins are experiencing rapid changes in the area covered by surface waters.

## **B.5. Isotope Monitoring Networks**

25. During the reporting period, through collaboration with Member States' institutions, GNIP expanded, with the establishment of additional 50 sampling stations in 23 Member States. Twelve institutions are new to the GNIP programme. Seven additional Member States participated in GNIP. The total number of active GNIP stations is currently 419. The GNIP database surpassed 147 000 records during the reporting period.

26. During 2021, at the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change in Glasgow, a new Memorandum of Understanding (MOU) that governs the GNIP programme between the Agency and the WMO was signed. The updated MOU reflects changes in the way in which sampling for GNIP is now undertaken, particularly the automation of weather stations which had traditionally collected the samples manually. Furthermore, a Technical Meeting was organized to discuss the method of sampling of actual precipitation, as well as the frequency at which the samples should be taken.

27. The Global Network of Isotopes in Rivers (GNIR) currently comprises 71 stations in 25 Member States, of which 9 were developed during the reporting period. These include five pilot sites incorporating sampling for nitrogen-15 in dissolved nitrate ion. Six additional Member States now contribute to the GNIR.

## **B.6. Capacity Development**

28. Generic and specialized training courses, technical workshops and e-learning materials were offered to build Member States' capacities and expertise in isotope hydrology. Teaching modules on isotope hydrology tools and methods were updated and made available on the Agency's website to provide basic knowledge on integrating isotope hydrology tools into water resources assessments. During 2021, three courses were offered in a virtual format: a Training Course on Advances in Data Processing and Interpretation Applied to Isotope Hydrology Studies, a Training Course on the Use of the Noble Gases in Hydrological Studies and a Training Course on the Fundamentals of Tritium Analysis and Data Processing for Hydrological Applications. A total of 103 participants from 58 Member States participated in these courses.

29. Group and individual training through fellowships continued under the TC programme despite the COVID-19 pandemic. Furthermore, substantial support (training materials, teaching programmes and agendas, and scientific oversight) was developed for the organization of online training courses.

# Zoonotic Disease Integrated Action (ZODIAC) Project

## A. Background

1. In resolution GC(65)/RES/11.A.4., the General Conference took note of the Director General's report as contained in document GOV/2021/27-GC(65)/3 submitted to the Board of Governors, as well as of the Director General's information paper "Zoonotic Disease Integrated Action Project, Early Detection and Global Response" as contained in GOV/INF/2020/13 submitted to the Board of Governors for information.
2. The General Conference recognized that the Agency has a long-standing practice of cooperation with other relevant international organizations and specialized agencies; and further recognized the importance of complementing the respective mandates of such organizations, as well as long-standing protocols that guide cooperation such as Taking a Multisectoral, One Health Approach: A Tripartite Guide to Addressing Zoonotic Diseases in Countries (the Tripartite Zoonoses Guide), which addresses collaborative efforts to address health risks at the human–animal–environment interface.
3. The General Conference noted that zoonotic diseases such as COVID-19, including vector-borne diseases such as malaria, yellow fever, chikungunya fever, and dengue fever, have significant and long-term implications on human health and the socio-economic development of Member States.
4. The General Conference recognized the importance of nuclear science, technology and applications to detect, trace and control emerging pathogens that could develop into diseases and pandemics and further recognized the importance of making these technologies available to all Member States.
5. The General Conference noted that ZODIAC could support Member States and enhance their preparedness to address emerging and re-emerging zoonotic diseases, through the use of molecular biology nuclear and nuclear-derived methods, by enhancing capacity in Member States to detect, trace and respond to emerging pathogens that could develop into zoonotic diseases and pandemics.
6. The General Conference welcomed that ZODIAC would build upon existing, relevant Agency nuclear science and technology applications and structures, such as the VETLAB Network, and other delivery mechanisms of the technical cooperation (TC) programme.
7. The General Conference welcomed the reaffirmation by the Directors General of the IAEA and the Food and Agriculture Organization of the United Nations (FAO) of their commitment to the long-standing partnership between the two organizations, including in strengthening global capacity to detect, trace and respond to zoonotic diseases, through the use of nuclear and nuclear-derived techniques at all phases of disease development and further welcomed the expansion of the Revised Arrangement to include the "improvement of monitoring and controlling of transboundary animal, zoonotic and plant diseases" as a key area, integrating the Joint FAO/IAEA Centre laboratories' capacities into FAO's work on One Health.
8. The General Conference acknowledged that ZODIAC aims to build on the existing partnership between the IAEA and the FAO, to include coordination with the United Nations Environmental

Programme (UNEP), the World Health Organization (WHO) and the World Organisation for Animal Health (OIE).

9. The General Conference recognized that ZODIAC is also intended, through the use of nuclear and nuclear-derived techniques, to form part of the IAEA's support to Member States in combatting zoonotic diseases and preventing future pandemics, in collaboration and coordination with existing networks of laboratories, such as VETLAB.

10. The General Conference requested, in resolution GC(65)/RES/11.A.4, the Director General to report on the progress made in the implementation of this resolution to the Board of Governors and the General Conference at its sixty-sixth regular session.

## **B. Progress since the 65th Regular Session of the General Conference**

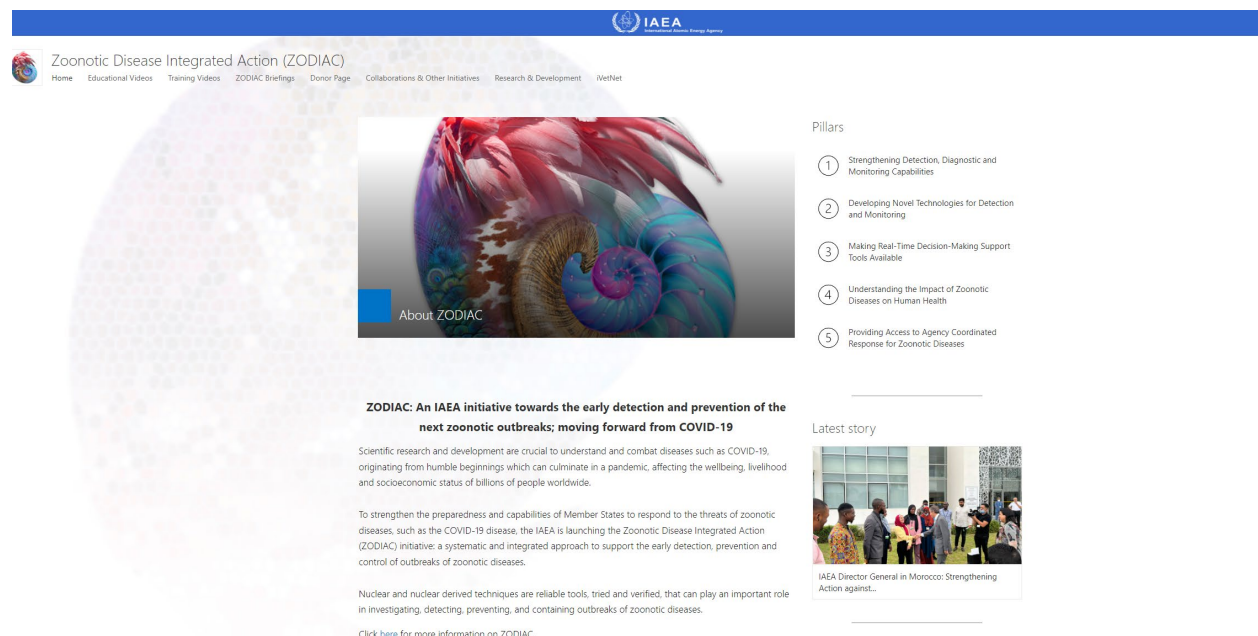
11. The Agency continued to respond to the needs and priorities of Member States by implementing all of its programmatic activities related to zoonotic diseases, pursuing its adaptive research and development (R&D) activities in the field of animal health at its Animal Production and Health Laboratory in Seibersdorf, coordinating the VETLAB Network and supporting Member States in the context of the COVID-19 pandemic through TC project INT0098.

12. A novel multiplex real-time polymerase chain reaction (real-time PCR) based assay for the detection and differential diagnosis of abortive diseases caused by important bacterial zoonotic agents was developed, laboratory validated and transferred to Member States (Botswana, Indonesia, Lesotho and Senegal). The test targets in a single assay four important bacteria causing severe diseases in animals and humans (brucellosis, Q fever, listeriosis and leptospirosis). In addition, a novel molecular-based multiplex assay (i.e. one test, multiple target pathogens) for detection and surveillance of zoonotic pathogens was designed and optimized. The advantage of this rapid and cost-effective test is safety, as it does not require live, infectious pathogens, and therefore it is accessible and sustainable for laboratories operating in limited resource countries. This test is useful for the detection and surveillance of flaviviruses, coronaviruses, orthomyxoviruses and lyssaviruses. These virus families include important emerging and re-emerging zoonotic pathogens, such as the West Nile fever and Zika viruses, severe acute respiratory syndrome coronavirus 2, Middle East respiratory syndrome coronavirus, avian influenza viruses and rabies viruses. The Agency has developed automated bioinformatics/data analysis pipelines for whole genome sequence analysis and PCR amplicon-based direct sequencing from clinical samples using the Ion S5 and Illumina sequencing platforms. These pipelines will be used by selected ZODIAC National Laboratories (ZNLs), with the sequencing platforms being delivered under Pillar 1 of ZODIAC through TC project INT5157 and will facilitate and strengthen ZNL capacity for the rapid and early detection and identification of zoonotic pathogens. The results of such R&D efforts undertaken by the Agency through its Animal Production and Health Laboratory and coordinated research projects (CRPs) will be immediately applicable through ZODIAC.

13. The Secretariat continued briefing Member States and their representatives on the development and implementation of ZODIAC through over 50 bilateral meetings, presentations to groups such as the G77 +China, and regional briefings. A total of four regional ZODIAC progress meetings took place to brief ZODIAC National Coordinators (ZNCs), representatives of designated ZNLs, and National Liaison Officers. Besides bilateral meetings with Member States' delegations, the Secretariat held an informal technical briefing on ZODIAC in May 2022. A dedicated ZODIAC online portal (<https://zodiac.iaea.org>) was created and launched during the informal technical briefing. This portal,



which serves as a ‘one-stop-shop’ for ZODIAC, hosts all the relevant information on ZODIAC, including updates on the number of ZNCs and ZNLs, educational videos, training materials; and provides access to recorded training events, as well as, through a secure password-protected gateway, to iVETnet, the platform developed as part of the VETLAB Network and used as a basis for connecting ZNLs.



*FIG. B.1. The Agency launched a dedicated ZODIAC online portal (<https://zodiac.iaea.org>) during the informal technical briefing to Member States in May 2022 which serves as a ‘one-stop-shop’ for ZODIAC. (Source: IAEA)*

14. As one of the lessons learned from the COVID-19 pandemic, ensuring synergies and complementarity of efforts with other organizations and initiatives has been at the core of the Secretariat’s efforts through ZODIAC. 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 for, and ability to respond in a timely manner to, zoonotic outbreaks. The Forum was attended by the Directors General of the FAO, the OIE and the WHO, as well as representatives from international initiatives such as the One Health High-Level Expert Panel, Preventing Zoonotic Disease Emergence (PREZODE) and Eklipt. The Forum called for closer coordination, collaboration and communication on the research, early detection and monitoring of zoonotic diseases as keys to containing future epidemics or pandemics.



*FIG. B.2. 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. (Source: IAEA)*

15. The complementarity and synergies between the Agency and the FAO, through the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, continued to be strengthened, further to the signing of the Revised Arrangement in 2021, to ensure that ZODIAC activities are delivered in an integrated manner.

16. The Agency and the WHO increased their regular dialogue on areas of potential common interest in order to identify how ZODIAC can strengthen global efforts coordinated by the WHO and ensure complementarity of efforts to maximize the support to Member States in areas such as animal sampling, training, information management and response to zoonotic diseases. Joint meetings are currently ongoing to define work plans and activities to be carried out that will culminate in the signing of arrangements specific to ZODIAC. The Agency joined the United Nations Biorisk Working Group and the Alliance for Health Security Cooperation and, in May 2022, the Agency, upon invitation by the WHO, attended the meeting of the One Health High-Level Expert Panel with representatives of the WHO, FAO, OIE and UNEP, as well as 26 international experts who have a range of technical knowledge, skills and experience relevant to One Health. In May 2022, the Agency was invited by the WHO to participate in and engage with the Global Strategic Preparedness Network (GSPN) for country health emergency preparedness capacity building to be launched in October 2022. The GSPN elaborates on the WHO International Health Regulations monitoring and evaluation framework, which serves as a tool to strengthen country capacities based on One Health and whole-of-government approaches. The Secretariat continued engaging in technical discussions with the OIE on animal and zoonotic diseases in general and the ZODIAC initiative in particular.



*FIG. B.3. Director General Grossi and Head of Institut Pasteur de Dakar Amadou Alpha Sall sign Practical Arrangements in Dakar, Senegal, in November 2021 to address areas of common interest in the fight against zoonotic diseases. (Source: IAEA)*

17. In an effort to expand cooperation and coordination with relevant institutions and initiatives, the Agency signed, on the margins of the 65th regular session of the General Conference, a Letter of Intent with PREZODE. PREZODE is an international initiative led by France that aims at understanding the risks of emergence of zoonotic diseases, and at developing and implementing innovative methods to improve prevention, early detection and resilience to ensure rapid response to emerging infectious diseases of animal origin. Since the signing, the Agency has participated in relevant workshops and working groups organized by PREZODE alongside participants from more than 130 research organizations, non-governmental organizations, and other initiatives. In November 2021, the Agency signed Practical Arrangements with the Pasteur Institute of Dakar (IPD) to increase cooperation under ZODIAC. The Practical Arrangements aim at addressing the common interests of the Agency and the IPD in fighting zoonotic diseases and supporting research and development activities. In the context of the Practical Arrangements, the Agency is planning a regional training course for Africa on generic verification of standard operating procedures for serology and molecular diagnostic at ZNLs, to be hosted by the IPD.





*FIG. B.4. On the side-lines of the IAEA's General Conference, representatives of the ZODIAC initiative and PREZODE underlined their commitment to work together by signing the PREZODE Declaration of Intent on fighting zoonotic diseases. (Source: IAEA)*

18. To benefit from the available international expertise for the development and implementation of ZODIAC, the Agency established the ZODIAC Ad-Hoc Scientific Panel (ZOSP), which is composed of independent scientists and experts in fields related to zoonotic diseases. The main roles of ZOSP members are to share and exchange scientific knowledge with the Secretariat on the latest innovations and techniques in fields related to zoonotic diseases; and to provide technical and scientific advice on ZODIAC-related matters, including peer reviews of relevant documents upon the request of the Secretariat. ZOSP members could also support partnership and outreach activities.

19. As of May 2022, the Agency had received the nomination of ZNCs from the national authorities of 149 Member States, and the ZNCs of 125 Member States had designated their ZNLs. Based on a technical assessment of the local needs performed in consultation with ZNL staff, the Agency initiated the procurement of equipment.

20. ZODIAC is making full use of the mechanisms available through the TC programme. The procurement of equipment and the delivery of training and information meetings is implemented through TC project INT5157, which supports Pillar 1 of ZODIAC. To date, a total of €5.66 million has been dedicated to capacity building and, by leveraging information and communication technologies, where possible, the training courses and workshops have reached over 1000 participants from 95 Member States.

21. Procurement was carried out for ZNLs (20 serology and molecular diagnostic packages and five whole genome sequencing packages) in 25 Member States. The next batch of procurement was initiated for ZNLs (nine serology and molecular diagnostic packages and four whole genome sequencing packages) in another 13 Member States. This procurement was made possible through the generous contribution of Japan, and further procurement will continue as funds become available.

22. Owing to COVID-19-related travel restrictions, the Agency used virtual means to implement some of the training courses and meetings planned under TC project INT5157. In February 2022, in partnership with the FAO, the Agency organized two virtual interregional training courses for laboratory technicians and experts to improve their testing procedures by aligning them with those of veterinary diagnostic reference laboratories; the training attracted more than 500 participants from 94 countries. In March 2022, the Agency hosted the first meeting of the Senior Expert Team to Implement Bio-risk Management Systems in ZODIAC National Laboratories with 20 experts representing the FAO, the OIE, the United States Centers for Disease Control and Prevention, the National Institute for Communicable Diseases of South Africa, and the Africa Centres for Disease Control and Prevention. In April 2022, the Agency held two virtual interregional training courses on the use of Agency genetic sequencing services, attracting more than 400 participants from over 90 Member States; these training courses resulted in 85 new registrations for the Agency's sequencing services. In May 2022, the Agency hosted the first group fellowships on whole genome sequencing at its Seibersdorf laboratories. In May 2022, the Agency also organized a virtual interregional workshop on current developments in whole genome sequencing platforms and bioinformatic data processing, which was attended by 12 international experts and over 150 participants. In addition to training ZNLs on whole genome sequencing, the latter workshop initiated the workflows that will lead to the establishment of service-based whole genome sequencing procedures, which will be accessible to all ZNLs.

23. Drawing lessons from the COVID-19 pandemic, which demonstrated the importance of preparedness and immediate response, increasing Member States' capacities for detection of zoonotic diseases is at the core of ZODIAC. In June 2022, following the outbreak of monkeypox on three continents, a disease which, until then, had been endemic to central Africa, as well as the outbreak of Lassa fever in Africa, the Agency organized a virtual "ZODIAC Workshop on Monkeypox and Lassa Fever Infections in Animal Reservoirs and the Risks for Public Health Transmission" joined by experts from FAO and WHO. Maximizing the benefits of the knowledge and equipment acquired at ZNLs through ZODIAC and/or in the context of the Agency's response to the COVID-19 pandemic, the workshop provided information on the two diseases, including their characteristics, epidemiology, genetic specificities and the relevant standard operating procedures for diagnosis. The workshop, open to ZNCs as well as representatives of ZNLs, national veterinary laboratories, recipients of COVID-19 assistance and Permanent Missions, will be followed by hands-on training courses under TC project INT5157, to be implemented in different regions in late 2022.



*FIG. B.5. IAEA Director General Grossi delivers his opening remarks at the ZODIAC Workshop on Monkeypox and Lassa Fever Infections in Animal Reservoirs and the Risks for Public Health Transmission joined by IAEA DDG-NA Najat Mokhtar and IAEA DDG-TC Hua Liu in June 2022. (Source: IAEA)*

24. Building upon and leveraging existing Agency mechanisms to ensure efficiencies is critical for the implementation of ZODIAC. The ZODIAC initiative was built upon the lessons learned and the experience of the VETLAB Network established in the Africa and Asia and the Pacific regions. To date, most of the VETLAB Network members are also designated ZNLs. iVetNet, a key component of the VETLAB Network, has reached 1969 affiliated institutions worldwide. iVetNet is being used by Member States as an effective channel for receiving updated information on diagnostic laboratory techniques and by the Secretariat to inform activities related to zoonotic and transboundary animal diseases. iVetNet is now accessible through the ZODIAC online portal and has become an integral part of the initiative.

25. ZODIAC also relies on the use of Agency coordinated research activities and the Peaceful Uses Initiative (PUI). Under Pillar 2 of ZODIAC, the Secretariat, in consultation with international experts, including experts from the FAO and the OIE, has developed four research projects entitled “Enhancing laboratory preparedness for the detection and control of emerging and re-emerging zoonotic diseases — ZODIAC”, one per geographic region, which will involve the relevant ZNLs and focus on the relevant priority diseases and tools for the region concerned. These research projects aim to enhance laboratory preparedness for the detection and control of emerging and re-emerging zoonotic diseases through the development and validation of immunological and molecular tools. Each of the projects will include 3 to 6 advanced laboratories that will assist in developing diagnostic tools and 16 ZNLs for the testing and validation of those tools. Through a PUI project, essential research was conducted on the detection of emerging and re-emerging transboundary animal and zoonotic pathogens at the animal–human interface to develop laboratory tools enabling Member States to conduct research and surveillance on the circulation and origin of animal and zoonotic diseases. This will also strengthen the preparedness as well as the diagnostic and research capacities of veterinary laboratories for emerging zoonotic pathogens. Under Pillar 4, a CRP entitled “ZODIAC Disease Phenotype Observatory” was developed, aiming at characterizing disease-specific patterns in the context of zoonotic disease-affected patients. The Secretariat, in collaboration with a group of imaging specialists from Austria, Egypt, France, Greece, the Republic of Korea and the United Kingdom, developed the framework for the data collection process and handling of images, as well as anonymization and data confidentiality. The clinical protocol

has now been finalized and the selection of the participating centres has been initiated by establishing a network of institutions to take part in the project.

26. As part of its resource mobilization efforts, the Secretariat presented the ZODIAC initiative to several global and regional development banks and funds, such as the World Bank, the Islamic Development Bank, the Inter-American Development Bank, the Asia Development Bank, the Kuwait Fund for Arab Economic Development and the Arab Fund for Economic and Social Development. Reaching out to the private sector, the Secretariat posted descriptions of the equipment needed for ZNLs on the United Nations Global Marketplace, and initiated discussions with major information technology companies for support in artificial intelligence and data management needs under Pillar 4. As of July 2022, resource mobilization efforts had led to generous contributions from 14 Member States including Belgium, Bulgaria, Estonia, France, Israel, Japan, Korea, Kuwait, Morocco, Pakistan, Poland, Portugal, Switzerland, and the United States of America, amounting to €10.4 million received and/or pledged.





# Plan for Producing Potable Water Economically Using Small and Medium Sized Nuclear Reactors

## C. Background

1. In resolution GC(62)/RES/9.A.4, the General Conference requested the Director General to continue consultations and strengthen interactions with interested Member States, the competent organizations of the United Nations system, regional development bodies and other relevant intergovernmental and non-governmental organizations in activities relating to seawater desalination using nuclear energy.
2. The General Conference also stressed the need for continued strengthening of international cooperation in the planning and implementation of nuclear desalination demonstration programmes through national and regional projects open for the participation of any interested country. It also requested the Director General, subject to the availability of resources, to continue to increase the Secretariat's activities in capacity building (including training and education) on nuclear desalination projects to bridge the gap among users/vendors/operators/regulators.
3. In resolution GC(65)/RES/11.A.7, the General Conference requested the Director General to report on progress made in the implementation of resolution GC(62)/RES/9 to the Board of Governors and to the General Conference at its sixty-sixth (2022) session.

## D. Progress Since the 62nd Regular Session of the General Conference

4. The new membership of the Technical Working Group on Nuclear Desalination for the period 2021–2024 was established.
5. The Agency collected input on the state of nuclear desalination projects and programmes from a select group of desalination experts on the most recent developments and advances in desalination technologies, which make them extremely competitive against nuclear-driven desalination (in particular reverse osmosis coupled with renewables). This provided a forum for discussion among experts on possible areas where nuclear energy could offer a real advantage for the production of potable water versus low-carbon alternatives, thus best informing the planning of future activities aimed at providing MS the best information on this issue.
6. Within the Agency-wide Platform on SMRs and their Applications, the Agency has created a task force on using small modular reactors for electric power generation and nuclear desalination in preparation for a workshop in 2022 followed by an expert mission to Jordan.



*FIG. B.1. Nuclear desalination plant at the Karachi nuclear power plant in Pakistan. (Photo: Pakistan Atomic Energy Commission)*

7. The Agency launched a new coordinated research project entitled “Role of Nuclear Cogeneration within the Context of Sustainable Development”, which includes desalination. The aim of this CRP is to provide approaches, case studies, and supporting data for techno-economics assessment of desalination projects, as part of a broader emphasis on nuclear cogeneration. Another aim of this CRP is to identify and develop technological aspects and advances to increase the competitiveness of various cogeneration options, including desalination.

# Nuclear power applications

## Introduction

### A. Background

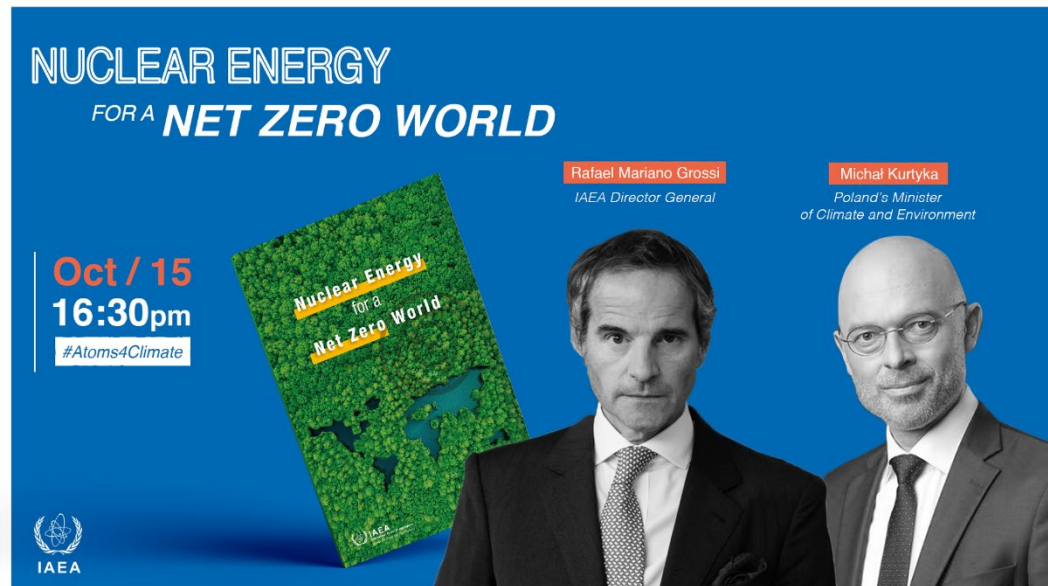
1. In resolution GC(65)/RES/11.B.1, the General Conference affirmed the importance of the role of the Agency in facilitating the development and use of nuclear energy for peaceful purposes, in fostering international cooperation among interested Member States, and in disseminating well-balanced information on nuclear energy to the public. It also encouraged the Agency to continue its support to interested Member States in building their national capacities in the operation of nuclear power plants and their nuclear power infrastructure when embarking on new nuclear power programmes.
2. The General Conference also encouraged Member States that are considering developing nuclear power to voluntarily use the support provided by the Agency to Member States on energy planning and assessment of energy systems in relation to environment, climate and economic factors and requested the Agency to continue its services to help interested Member States in this regard. It commended the Secretariat's efforts in providing comprehensive information on nuclear energy's potential as a low carbon energy source and its potential to contribute to mitigating climate change and encouraged the Secretariat to work directly with Member States upon request and to continue to extend its activities in these areas, including the Paris Agreement.
3. The General Conference also stressed the importance, when planning, deploying, or decommissioning nuclear energy facilities, including nuclear power plants and related fuel cycle activities, of ensuring the highest standards of safety and emergency preparedness and response, security, non-proliferation, and environmental protection, of being informed of the best available technologies and practices, of continuously exchanging information on R&D addressing safety issues, of strengthening long-term research programmes to learn about severe accidents and related decommissioning activities, and of enabling continuous improvement in this regard; and valued the role of the Agency in fostering exchange of expertise and discussions within the international nuclear community on such issues.
4. The General Conference, in resolution GC(65)/RES/11.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its sixty-sixth (2022) session. The reporting period of the given document covers September 2021 – August 2022.

### B. Progress Since the 65th Regular Session of the General Conference

5. In September 2021, the Agency published the 41st edition of Reference Data Series No. 1 *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050*. For the first time in a decade, the

high case projection was revised upwards from the previous edition, with a projected capacity of 792 GW(e) by 2050, close to the nuclear capacity modelled by the International Energy Agency's (IEA's) Net Zero by 2050 roadmap published in 2021.

6. In October 2021, the Agency published *Nuclear Energy for a Net Zero World* ahead of the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26). This publication, which includes high-level statements from nine Member States, provides a well-researched analysis on the different ways that nuclear energy can help decarbonize the world's energy system while contributing to resilient and sustainable economies.



*FIG. B.1. The Agency released the Nuclear Energy for a Net Zero World publication at a high-level conversation between Director General Rafael Mariano Grossi and the then Minister of Climate and Environment of Poland Michał Kurtyka ahead of COP26*

7. To prepare for an effective and impactful participation of the Agency at COP26, an internal cross-Departmental coordination group was set up at the Agency. Input from Member States was sought to shape the contribution of the Agency at COP26. The Agency was involved in a large number of events at COP26, with Director General participating in high level nuclear events on the French and United Kingdom pavilions, as well as on the Agency's shared pavilion event entitled "Nuclear Innovation for a Net Zero World". The Agency was also actively involved in a side event led by the United Nations Department of Economic and Social Affairs, in an event on resilience co-hosted with the World Meteorological Organization, in an event on the COP26 Resilience Hub with the IEA, and in an event organized by the Vienna Energy Club on innovation. The Agency also organized a specific youth event at COP26, which included as speaker the winner of the IAEA Net Zero Challenge competition held during the 65th regular session of the General Conference.



*FIG. B.2. IAEA Director General Rafael Grossi with the IAEA Net Zero Challenge winner Claire Li from Singapore*

8. In April 2022, the Agency organized, in partnership with the Nuclear Innovation: Clean Energy Future initiative of the Clean Energy Ministerial, a webinar entitled “Investing in Low Carbon Technologies: Job Creation for Just Energy Transitions”, with speakers from the IEA, the International Renewable Energy Agency, the World Nuclear Association and an embarking country Kenya, to discuss the importance of investments in clean energy technologies, including nuclear power, in terms of economic growth and jobs, which are necessary to ensure a just transition away from fossil fuel activities.

9. The Agency released, in September 2021 a publication entitled *Financing Nuclear Power Plants* (IAEA-TECDOC-1964), which presents the outcome of a coordinated research project. Based on the experience of those Member States recently involved in financing nuclear projects, the publication identifies the lessons which could be drawn relating to the sources of financing, the nature of the financing process and the barriers to financing nuclear projects.

10. In efforts to further analyse the technical and economic cost drivers for economic sustainability of nuclear power operations, especially with regard to decisions of Member States concerning the long term operation of nuclear power plants, and to determine the value of nuclear power in the energy mix considering environmental conditions, the Agency performed independent analyses, with computational capabilities developed in-house, to quantify the value of nuclear in a transition to a net-zero system with varying amounts of hydrogen deployment.

11. To strengthen the Agency’s activities in the area of fusion science and technology for ITER and demonstration fusion power plants, the Agency organized the Third Research Coordination Meeting on Data for Atomic Processes Related to Neutral Beams in Fusion Plasma as a virtual event in November 2021, with 12 participants from 9 Member States. The participants reviewed their progress in evaluating

fundamental data for modelling penetration and photoemission processes of the neutral beams used for heating and for diagnostic purposes in fusion plasmas.

## Integrated Nuclear Infrastructure Review Missions



12. The Agency continued to maintain and strengthen its assistance and advisory services to Member States embarking on or expanding a nuclear power programme through Integrated Nuclear Infrastructure Review (INIR) missions to assess the status of nuclear power infrastructure development. INIR Phase 1 Missions to Uganda (November/December 2021) and to Sri Lanka (April 2022, postponed from 2021) were conducted in this regard upon the respective Member State's request.



*FIG. B.3. The conclusion of the Agency's eight-day mission to Uganda to review the country's infrastructure development for a nuclear power programme.*



13. The 16th annual Technical Meeting on Topical Issues in the Development of Nuclear Power Infrastructure, held as a virtual meeting in March 2022, was attended by 87 participants representing 34 Member States and one international organization. The meeting continued to be the main forum for representatives from countries expanding, introducing or considering a nuclear power programme to provide updates on their progress, share good practices and offer lessons learned from implementing the Agency's Milestones approach to establish the infrastructure required for a safe and successful nuclear power programme, and prioritizing and sequencing the activities needed.

14. The Agency continued to deliver Integrated Nuclear Infrastructure Training (INIT) courses to increase awareness and understanding of the Milestones approach, in both a two-step approach and a face-to-face approach where feasible. Training was provided to around 268 participants from 39 countries in 15 interregional courses and workshops between September 2021 and August 2022. Additionally, in December 2021, within the framework of INIT, the Agency organized a course in Paris-Dunkerque-Gravelines, France, during which 32 participants from 23 Member States learned about economic and financing aspects to consider when developing a nuclear power programme.

15. The Advisory and Peer Review Service Committee (APReSC) was established in 2021 with the objectives of harmonizing, improving and monitoring the efficiency and effectiveness of the advisory and peer review services provided by the Agency. Since its launch, APReSC has held four meetings to harmonize the definitions, develop a template for guidelines for peer review missions, and develop performance indicators for peer review services.

16. In November 2021, the Japan Atomic Energy Agency was designated as a new Collaborating Centre on decommissioning in the areas of radiological characterization for decommissioning, and nuclear security.

17. The Agency continued to provide capacity building in energy planning to its Member States, providing training on a whole suite of energy modelling tools to help Member States assess different pathways to meet their energy needs while considering their environmental, climate and sustainable development objectives. In this context, the Agency trained participants on conducting strategic environmental assessments for national nuclear power programmes in accordance with the relevant Agency guidelines during a workshop on strategic environmental assessments for nuclear power programmes in November 2021.

18. The Agency continued to underline effective stakeholder involvement, including public communication, as one of the key issues in the Milestones approach, and in November–December 2021 organized a virtual Technical Meeting on Stakeholder Involvement in Nuclear Power Programmes with the participation of 52 attendees from 16 Member States and two international organizations.

19. In December 2021, the Agency organized the Biennial Forum of the International Decommissioning Network in hybrid format. The Forum was attended by 80 participants from 28 Member States. The meeting provided a forum for vendors/designers, regulators and decommissioning implementing organizations to discuss the challenges, needs and gaps to be addressed in this area.

20. The Agency published, in December 2021, *Decontamination Approaches During Outages in Nuclear Power Plants — Experiences and Lessons Learned* (IAEA-TECDOC-1946), which consolidated, updated, reorganized and expanded upon information contained in other Agency publications related to the subject.

21. The publication *Managing the Decommissioning and Remediation of Damaged Nuclear Facilities* (IAEA-TECDOC-1989), published in 2021, summarizes the outcomes of the Agency-led International Project on Managing the Decommissioning and Remediation of Damaged Nuclear Facilities and provides guidance based on case studies and lessons learned.



22. In December 2021, the Agency delivered a webinar on an integrated approach to decommissioning within a multi-facility site that attracted 76 participants from 26 Member States. The Agency published *Decommissioning at a Multifacility site: An Integrated Approach* (IAEA Nuclear Energy Series No. NW-T-2.13) in June 2022.

23. The Agency created two IAEA Connect-based Networks on Nuclear Power Plant Life Management and Innovation to Support the Global Fleet of Operating Nuclear Power Plants. Both networks leverage the very successful experience of longstanding Agency Networks.

24. In October 2021, a pioneering Technical Meeting on Artificial Intelligence for Nuclear Technology and Applications, held virtually, provided an international, cross-cutting forum to discuss, identify and foster cooperation on artificial intelligence (AI) methodologies and tools that have the potential to advance nuclear science, technology and applications. The virtual programme consisted of sessions focused on food and agriculture, human health, nuclear data, nuclear fusion, nuclear physics, nuclear power, nuclear security, radiation protection, safeguards verification, water and the environment, and the ethics of nuclear and AI.

25. In line with the Agency's commitment to gender equality both within the Secretariat and in its programmes, the Agency launched the Women in Fusion network at [womeninfusion.org](http://womeninfusion.org) to support networking for gender balance in fusion communities, and to support efforts to promote women at all educational levels and increase the visibility of work carried out by women in fusion.

26. To promote gender equality and diversity and to encourage Member States to establish an inclusive workforce within their nuclear industry, the Director General launched the IAEA Marie Skłodowska-Curie Fellowship Programme (MSCFP) in March 2020, which aims to inspire and encourage women to pursue a career in nuclear science and technology, nuclear safety and security, non-proliferation or nuclear law, by providing scholarships for masters programmes in nuclear related fields and an opportunity to pursue internships facilitated by the Agency relating to their field of study.

27. In 2021, the Agency set up the Technical Working Group on Nuclear Power for Low-Carbon Energy Systems (TWG-NPLCES). The TWG-NPLCES met for the first time in December 2021, with representatives from 12 Member States and five international organizations. The discussions covered the topics of nuclear energy, sustainable development and climate change; energy modelling, projections and scenarios; and energy planning and support to Member States. The membership of the TWG-NPLCES was increased in 2022 to achieve better regional representation.

# Achievements to date

Cumulative numbers from 2020 and 2021 cycles

## 1042

Applications received

## 210

Students selected



## 93

Nationalities



Studying in

## 53

Member States

## By August 2022...

## 73

students are expected to complete their Master's programme

## 55

students are expected to pursue an internship facilitated by the IAEA



*FIG. B.4. Results to date of the IAEA Marie Skłodowska-Curie Fellowship Programme (MSCFP), which aims to inspire women to pursue a career in nuclear science and technology, nuclear safety and security, non-proliferation or nuclear law*



*FIG. B.5. Participation of MSCFP fellows at the International School on Nuclear Security and the International Seminar on the Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment, 15–26 November 2021*

28. To date, the MSCFP has received 1042 applications. The 210 selected students represent 93 Member States studying in 53 countries around the globe. Under the MSCFP, by August 2022 73 students are expected to have completed their master's programme and 55 to have pursued internships facilitated by the Agency. The internships take place across the Agency's technical Departments and Collaborating Centres, as well as at partner organizations and in industry. The MSCFP recipients also benefit from participation in various technical and training events, as well as conferences.

# IAEA Communication, Cooperation with Other Agencies and Stakeholder Involvement

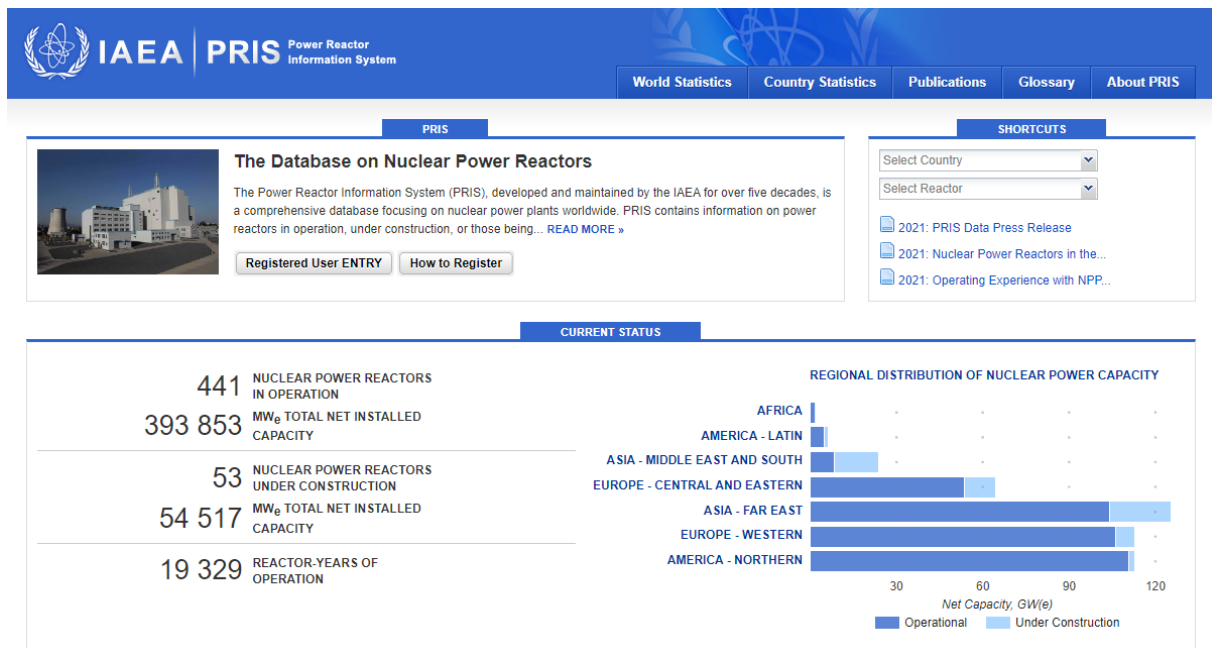
## A. Background

1. In resolution GC(65)/RES/11.B.2, the General Conference encouraged the Secretariat to continuously assist Member States in enhancing public awareness and understanding of peaceful uses of nuclear energy, including by publishing reports on stakeholder involvement and public information as well as organizing conferences, technical meetings and workshops, among other mechanisms.
2. The General Conference also requested the Secretariat to continue cooperation with international initiatives such as UN-Energy; encouraged strengthening mutual cooperation between Member States by exchanging information through international organizations such as the IAEA, the Organization for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA), the International Framework for Nuclear Energy Cooperation (IFNEC), the World Nuclear Association (WNA) and the World Association of Nuclear Operators (WANO); encouraged the Secretariat to cooperate with national and international industrial organizations for standardization; and recommended that the Secretariat continue to explore opportunities for synergy between the Agency's activities and those pursued under other international initiatives such as the Generation IV International Forum (GIF), IFNEC, the European Sustainable Nuclear Industrial Initiative (ESNII) and the International Thermonuclear Experimental Reactor (ITER).
3. Furthermore, the General Conference welcomed the revision of the Nuclear Energy Series structure, encouraged the Secretariat to continue to develop Nuclear Energy Series documents as a more integrated, comprehensive and clearly organized set of publications to be maintained up-to-date and further encouraged the Secretariat to continue consolidating the drafting and review of Nuclear Energy Series publications to establish a single, systematic, and transparent process.
4. The General Conference, in resolution GC(65)/RES/11.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its sixty-sixth (2022) session.

## B. Progress Since the 65th Regular Session of the General Conference

5. The Agency's recent deployment of a new data acquisition and validation application for the Power Reactor Information System (PRIS) resulted in a streamlined and more efficient nuclear power data collection and dissemination process. The application's new data validation tests led to improvement of the data quality and contributed to improved classification of energy losses and better utilization of the outage coding system, which produced more accurate nuclear reactor performance indicator calculations. Also, the new data acquisition system significantly expanded data collection related to the nuclear reactor construction process which will benefit all Member States that are

developing new or expanding their nuclear programmes. The Agency provided access to data collected in PRIS through the PRIS public web page, which is one of the most popular Agency web pages with over 1.2 million pageviews and 170 000 unique users over the past year.



*FIG. B.1. The Agency is currently developing a project to revamp the Power Reactor Information System (PRIS) public web page by deployment of a multilayer, intuitive and innovative data exploration data browser. The Agency efforts to revamp the PRIS public web page experience strive to provide top level user experience and maximize utilization of all data to develop best statistical reports and infographics*



*FIG. B.2. The Agency's Power Reactor Information System (PRIS) is a comprehensive database focusing on nuclear power plants worldwide*

6. In late 2021, the Agency established the Nuclear Energy Stakeholder Engagement Coordination Committee (NESECC) to ensure consistent and coordinated support to Member States, monitor its efficiency and effectiveness and ensure internal coordination. NESECC held its inaugural meeting, which resulted in the development of a Stakeholder Engagement Strategy.

7. The Agency actively collaborated with international partners in human and organizational capacity building efforts. Through membership in the OECD/NEA's Working Group on Human and Organisational Factors (WGHOFF) and in the specific task force within it on learning and performance through the pandemic, the Agency continued to learn from, share with, and evolve improvements in human and organizational nuclear performance. Due to its leadership role in these efforts, the Agency was invited to present on tools and approaches to strengthen human and organizational performance during the March 2022 WGHOFF Plenary meeting, and to share its efforts to navigate through the complexities introduced by the pandemic. WANO continued to be an active and strategic partner in human and organizational capacity related publications. For example, WANO was an expert member of the drafting team for the publication entitled *Leadership in the Nuclear Organization*, an IAEA Nuclear Energy Series publication effort initiated in late 2021.

8. The Agency and WANO also continued cooperating through the New Unit Assistance Working Group (NUAWG) interface meetings organized on a regular basis. WANO participated in the Technical Meeting on Topical Issues in the Development of Nuclear Power Infrastructure in March 2022 and in the virtual meeting of the Technical Working Group on Nuclear Power Infrastructure in November 2021. Through the NUAWG, the Agency and WANO built synergies to optimize the Agency's services to ensure maximum added value and minimize the load on the organizations in the lead up to commissioning and operations.

9. IFNEC participated regularly in the annual TM on Topical Issues in Nuclear Power Infrastructure Development, sharing their knowledge and experience during the different sessions, as well as providing presentations on assistance and cooperation with embarking countries. Regular virtual cooperation meetings were also held with regional networks, such as the Association of Southeast Asian Nations (ASEAN) and the African Commission on Nuclear Energy (AFCONE), and the Agency further participated in three AFCONE and two ASEAN webinars.

10. The Agency consolidated cooperation with the OECD/NEA in the area of advanced nuclear systems and their applications. The Agency also strengthened cooperation with the OECD/NEA in the area of nuclear power and climate change, by inviting the NEA to contribute to one of the IAEA events organized at COP26. The Agency was also invited to join a panel discussion for the launch in May 2022 of an NEA report entitled *Meeting Climate Change Targets: The Role of Nuclear Energy*.

11. The Agency participated in the Organisation for Economic Co-operation and Development's Nuclear Energy Agency's (OECD/NEA's) Nuclear Science Committee in June 2022 for all scientific aspects of nuclear power generation and in the Working Party on International Nuclear Data Evaluation Co-operation in May 2022 and contributed to the Joint Evaluated Fission and Fusion library project with nuclear data evaluations for various nuclides.

12. The Agency established trilateral collaboration with the European Commission and the OECD/NEA to develop a common taxonomy and ontology for knowledge management in nuclear decommissioning; a joint report on such a taxonomy is being drafted.

13. The 57<sup>th</sup> Meeting of the Joint OECD/NEA–IAEA Uranium Group was held virtually in November 2021. It was attended by 47 experts representing 33 Member States and 3 international organizations, as well as by 13 guest experts from governments and the private sector, who provided thematic presentations, ranging from uranium market fundamentals to technological innovations and other

science-based interests relating to uranium exploration and production. The Group reviewed country presentations that outlined data provided for the Red Book 2022 country reports and was briefed on the progress of the Red Book digitization/database development.

14. In order to promote cooperation with the International Organization for Standardization with regard to the development of appropriate engineering and industry codes and standards in order to better respond to the needs of the Member States, the Agency established with “ISO TC/85 nuclear energy, nuclear technology and radiological protection” procedures to identify activities in which cooperation may be pursued.

15. The Agency also cooperated with various international organizations in order to support harmonization in codes and standards, design engineering and manufacturing of components for SMRs.

16. The Agency streamlined cooperation with the GIF in order to define the areas of cooperation for all six GIF nuclear systems as well as the cross-cutting Working Groups. The annual GIF–IAEA Interface Meeting was held in July 2022 and the Agency participated as an observer in regular meetings of the GIF Policy Group.

17. In addition to having a presence in IFNEC’s Steering Group, the Agency cooperates with IFNEC via its two Working Groups — the Infrastructure Development Working Group and the Reliable Nuclear Fuel Services Working Group. Representatives from IFNEC regularly participate in the annual Technical Meeting on Topical Issues in the Development of Nuclear Power Infrastructure, held most recently in March 2022 in a hybrid format.

18. The Agency continued to underline stakeholder engagement, including public communication, as one of the key issues in the Milestones approach. The Agency will initiate the development of a publication on stakeholder engagement in new nuclear power programmes, intended to become a supporting publication to the Milestones approach and to complement the overarching publication entitled *Stakeholder Engagement in Nuclear Programmes* (IAEA Nuclear Energy Series No. NG-G-5.1).

19. The Agency addressed this issue further during the virtual Interregional Training Course on Stakeholder Involvement for New Nuclear Power Programmes, held in August/September 2021 with 19 participants from 12 Member States.

20. The Agency published *Communication and Stakeholder Involvement in Radioactive Waste Disposal* (IAEA Nuclear Energy Series No. NW-T-1.16) in April 2022, which provides practical guidance on communication and stakeholder involvement for countries embarking on, relaunching or revising a disposal programme.



# Nuclear Fuel Cycle and Waste Management

## A. Background

4. In resolution GC(65)/RES/11.B.3, the General Conference recognized the importance of assisting Member States interested in uranium production to develop and maintain sustainable activities through appropriate technology, infrastructure and stakeholder involvement and the development of skilled human resources; encouraged the Agency to develop a guidance document with a step by step approach for countries considering or initiating a uranium production programme; and encouraged interested Member States to use the Uranium Production Site Appraisal Team (UPSAT) missions which support Member States in this field.

2. The General Conference also encouraged the Secretariat to assist interested Member States in analysing the technical challenges that may hinder the sustainable operation of nuclear fuel cycle facilities, such as ageing management issues.

3. Furthermore, the General Conference requested the Secretariat to continue and strengthen its efforts relating to the fuel cycle, spent fuel, and radioactive waste management, and to assist Member States to develop and implement adequate programmes, in accordance with relevant safety standards and security guidance. It also encouraged the Secretariat to promote information sharing to better integrate approaches to the back end of the fuel cycle that impact processing, transport, storage, and recycling of spent fuel and waste management, and to provide more information on all stages of waste management, including waste pre-disposal management and disposal, and thereby assisting Member States, including those embarking on nuclear power programmes, to develop and implement adequate disposal programmes, in accordance with relevant safety standards and security guidance.

4. In the same resolution, the General Conference requested the Agency to formulate guidance documents on decommissioning and action plans to support decommissioning, with a view to promoting the safe, secure, efficient, and sustainable execution of these activities, and to facilitate the systematic review of these guidance documents based on recent developments, as appropriate. It also encouraged the Agency to further strengthen its activities in the area of environmental remediation, and supported Member States in the adoption of best practices for managing naturally occurring radioactive material (NORM) residue/wastes and to remediate NORM contaminated sites.

5. The General Conference also encouraged the Agency to further strengthen its activities in support of the effective management of disused sealed radioactive sources (DSRS) through, inter alia, the development of Qualified Technical Centres for DSRS management and cooperative efforts to strengthen supporting information on the borehole disposal of DSRS, with a view to enhancing safety and security of DSRS in the long term.

6. The General Conference, in resolution GC(65)/RES/11.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its sixty-sixth (2022) session.

## **B. Progress Since the 65th Regular Session of the General Conference**

7. A Technical Meeting to Collect and Document Innovations in the Uranium Production Cycle was held virtually in June 2022. It was attended by 42 experts representing 22 Member States, who shared information and discussed recent technical innovations in uranium production, with a focus on uranium recovery from secondary and lower grade resources.

8. In December 2021, the Agency published *Milestones in the Development of National Infrastructure for the Uranium Production Cycle* as a preprint publication that describes the four phases of successive development in the uranium production cycle to achieve four corresponding milestones: (i) exploration, (ii) construction/commissioning of a uranium mine and processing facility, (iii) safe operation of a uranium mine and processing facility, and (iv) decommissioning and remediation.



In November 2021, the Agency published Russian language versions of *Fuel Modelling in Accident Conditions (FUMAC)* (IAEA-TECDOC-1889, published in English in December 2019) and *Analysis of Options and Experimental Examination of Fuels for Water Cooled Reactors with Increased Accident Tolerance (ACTOF)* (IAEA-TECDOC-1921, published in English in July 2020). The latter publication was also published in Chinese in May 2022.

9. In June 2022, the Agency organized a Technical Meeting on the Use of E-Tools for Competence Building in Decommissioning and Environmental Remediation, with 45 participants from 23 Member States and two international organizations. Participants discussed lessons learned from using e-learning, webinars and other e-tools and identified good practices.
10. The Third and the last Research Coordination Meeting on Management of Severely Damaged Spent Fuel and Corium was held in June 2022. The results of the CRP will be captured in a TECDOC on the same topic.
11. A Technical Meeting on Ageing Management and Life Extension of Nuclear Fuel Cycle Facilities was held virtually in December 2021. It was attended by 45 experts from 18 Member States and two international organizations, who exchanged their operating experience in operating ageing nuclear fuel cycle facilities.
12. In September 2021, the Agency published *Spent Fuel Performance Assessment and Research: Final Report of a Coordinated Research Project (SPAR-IV)* (IAEA-TECDOC-1975) that provides an overview of the technical issues related to wet and dry storage of spent fuel and summarizes the objectives and major findings of the research carried out within the framework of the coordinated research project (CRP) on spent fuel and storage system performance.
13. The First Research Coordination Meeting on Spent Fuel Characterization was held virtually in December 2021 and was attended by 30 chief scientific investigators and observers from 16 Member States and one international organization, who discussed progress on the individual projects under way and identified collaborative work to undertake in order to achieve the overall objectives of the CRP.
14. In December 2021, the Agency published Arabic, Chinese and Russian language versions of *Storing Spent Fuel until Transport to Reprocessing or Disposal* (NES No. NF-T-3.3, published in English in March 2019).
15. In December 2021, the Agency published Chinese and Russian language versions of *Behaviour of Spent Power Reactor Fuel during Storage: Extracts from the Final Reports of Coordinated Research Projects on Behaviour of Spent Fuel Assemblies in Storage (BEFAST I–III) and Spent Fuel Performance Assessment and Research (SPAR I–III) — 1981–2014* (IAEA-TECDOC-1862, published in English in February 2019).
16. The First Research Coordination Meeting on Spent Fuel Research and Assessment was held virtually in May 2022. It was attended by 27 experts representing 7 Member States and 1 International Organization who shared details of their projects relevant to the scope of the CRP on assessing the performance of spent fuel during (wet and dry) storage and discussed the overall CRP outputs. In addition to the final TECDOC, the CRP team will develop e-learning modules on the degradation mechanisms of spent fuel and participate in webinars to disseminate the CRP findings.
17. A Technical Meeting to Identify Opportunities and Challenges in the Back End of the Fuel Cycle for Evolutionary Accident Tolerant Fuels was held virtually in June 2022. It was attended by 33 experts representing 16 Member States and one International Organization, who developed a working definition of eATFs and exchanged on the work underway to understand their impact on back-end activities and to identify key questions and information needed. The experts commonly recognized the importance of having irradiated fuel characterization and testing to support model validation and to understand potential back-end impacts.
18. A meeting of the International Radioactive Waste Technical Committee was held in May 2022, with the attendance of 23 waste experts in-person and 8 virtually, representing 19 Member States and four international organizations. The experts discussed the strategies, implementation, technologies and

methodologies of radioactive waste management in accordance with relevant safety standards and security guidance, including maintaining transversal connectivity of the radioactive waste management programme with other relevant fields of work in the Agency.

19. The publication entitled *Policy and Strategies for Radioactive Waste Management* (IAEA Nuclear Energy Series No. NW-G-1.1), published in English in 2009, was translated into Spanish and published in March 2022.

20. In March 2022, the Agency organized a Technical Meeting on International Safeguards in the Design of Radioactive Waste Management Programmes in a hybrid format. Attended by 30 Member States, the meeting discussed and reviewed a draft publication on this subject.

21. The International Conference on Radioactive Waste Management: Solutions for a Sustainable Future, held 1–5 November 2021, fostered information exchange on current progress and demonstrated solutions for radioactive waste management.



*FIG. B.1. Participants of the International Conference International Conference on Radioactive Waste Management: Solutions for a Sustainable Future, held in Vienna, discussed solutions for the safe and responsible management of radioactive waste.*

23. The Agency published *Decontamination Approaches During Outage in Nuclear Power Plants - Experiences and Lessons Learned* (IAEA-TECDOC-1946) in 2021. Draft publication *Experience in the Management of Radioactive Wastes after Nuclear Accidents* (IAEA Nuclear Energy Series No. NW-T-1.31) is currently available as a preprint.

24. The Agency published *Design Principles and Approaches for Radioactive Waste Repositories* (IAEA Nuclear Energy Series No. NW-T-1.27) in 2021.

25. At the Agency's Workshop on Waste Management for Fusion, held in October 2021, experts developed guidelines specific for radioactive waste management for future fusion demonstration and pilot power plants. The workshop was attended by 45 participants from 15 Member States and two international organizations.

26. The joint Abdus Salam International Centre for Theoretical Physics (ICTP)–IAEA International Schools support the Agency in knowledge transfer, education and training, and technical innovation.

The Joint ICTP–IAEA International School on Radioactive Waste Package Performance Testing was held in November 2021, and a school on the physical basis for radionuclide migration (storage, disposal and contaminated sites) is in preparation for its implementation in November 2022.

27. A virtual Technical Meeting on the Spent fuel and Radioactive Waste Information System (SRIS) was held in November–December 2021. Feedback from 56 participants on their experience with the system was collected. The event also provided an overview of the SRIS features and its benefits to the new national coordinators. The public web page on SRIS was launched in December 2021.

28. In response to a request by Member States for more information on disposal management of radioactive waste, the Agency held a Technical Meeting on Challenges and Options for Disposal of Graphite and Radium-Bearing Waste and Other Long-Lived Low Level Radioactive Wastes in November 2021. Thirteen Participants from 9 Member States discussed the challenges in managing this type of waste and reviewed potential technologies and options for the disposal of reactor graphite waste.

29. In April 2022, a forum to discuss and share the current approaches in the development and deployment of geopolymers as an immobilization matrix for radioactive waste was provided by the Technical Meeting on the Status and Use of Geopolymers to Immobilize Radioactive Waste that was attended by 48 participants from 31 Member States. The outcome of this fully virtual meeting indicated that geopolymer conditioned waste would require additional knowledge regarding waste form testing and durability of the waste form.

30. In December 2021, the Technical Meeting on Advancing Human Resource Development and Competence Building for Decommissioning with 39 participants from 16 Member States and one international organization was organized by the Agency in cooperation with Sogin in Piacenza, Italy. The focus of the meeting was on capacity building for decommissioning, in particular on the use of new and innovative technologies to advance decommissioning projects.

31. In January 2022, a webinar on the global status of nuclear decommissioning provided 82 participants from 31 Member States with outcomes of the overview and analysis of status, trends and issues in implementing decommissioning projects at shutdown nuclear power plants, nuclear fuel cycle facilities and research reactors. A resulting Nuclear Energy Series publication entitled *Global Status of Decommissioning* has been drafted.

32. In May 2022, the International Workshop on Lessons Learned from the Implementation of Decommissioning Projects for Water Cooled, Water Moderated Power Reactors (WWERs) with 45 participants from 15 Member States and two international organizations was organized by the Agency in cooperation with the JAVYS Nuclear and Decommissioning Company in Trnava, Slovakia. Participants exchanged lessons learned on both organizational and technological aspects of ongoing decommissioning projects.





*FIG.B.2. Participants of the International Workshop on Lessons Learned from the Implementation of Decommissioning Projects for Water Cooled, Water Moderated Power Reactors (WWERs) observing dismantling activities in the controlled area during a site visit to the Bohunice V1 nuclear power plant.*

33. In April 2022, the Agency delivered a webinar on human resources development for decommissioning, attended by 52 participants from 22 Member States, to consider the main issues and challenges in ensuring a skilled workforce to implement decommissioning projects. In July 2022, this was followed by the Technical Meeting on Human Resource Development for Decommissioning held in Vienna, which aimed to exchange Member States' experience on the topic. The publication entitled *Training and Human Resource Considerations for Nuclear Facility Decommissioning* (IAEA Nuclear Energy Series No. NG-T-2.3 (Rev. 1)) was published in June 2022.

34. In August 2022, the Agency will organize the Technical Meeting on New and Emerging Technologies to Advance Decommissioning Projects to discuss values and limitations in using state-of-the-art digitalization technologies to design and advance decommissioning activities.

35. In March–April 2022, the Agency delivered a string of webinars devoted to different instruments to support decision making in environmental remediation projects, providing more than 100 participants from 39 Member States with updates on recent developments on the topic.

36. In October and November 2021, the Agency organized two webinars, disseminating good practices from Spain and France, respectively, in the remediation of former uranium mining sites. These webinars were attended by more than 100 participants, representing 35 Member States.

37. The webinar on the environmental assessment of legacy trench sites in May 2022 provided 89 participants from 36 Member States with information on good practices in safety assessment and environmental modelling.



38. In October 2021, the Agency delivered the Workshop on the Characterization of Radioactively Contaminated Land in Vienna and Seibersdorf, Austria, with 22 participants from 15 Member States, including practical exercises on sampling and characterization.
39. In December 2021, the Agency delivered the webinar on management options for NORM residues, providing 129 participants from 43 Member States with an analysis of challenges and issues and examples of good practices and solutions.
40. The proceedings of the International Conference on Management of Naturally Occurring Radioactive Materials (NORM) in Industry were published in May 2022.
41. The Agency provides assistance in the effective implementation of the disposal of DSRS in a borehole disposal facility. The Borehole Disposal Project in Malaysia, the first of its kind, is now entering the construction and disposal operation phase. The Agency provides support and assistance, upon request, for the completion of the project, expected at the end of 2022.
42. A pilot test for a Qualified Technical Centre was successfully conducted in May 2022, in cooperation with the National Centre for Nuclear Energy, Sciences and Technology in Morocco. Following the pilot test, the application processes and assessment methodologies are now in the final draft of finalization.
43. Strengthening the capabilities of Member States in the management of sealed radioactive sources continued by capturing experiences and lessons learned from Member States through the Technical Meeting on National and International Experiences in the Reuse and Recycling of Disused Sealed Radioactive Sources held in April 2022 and the Technical Meeting on Lessons Learned from the Management of Disused High Activity Sources held in May 2022.
44. The Global Radium-226 Management Initiative that was launched in December 2021 started showing success. Under this initiative, the Agency facilitates contact between Member States possessing legacy radium-226 sources and Member States with the capabilities to recycle sources.
45. The Agency's publication *Management of Disused Sealed Radioactive Sources* (IAEA Nuclear Energy Series No. NW-T-1.3) was issued in French and Spanish in May 2022.

# Research Reactors

## A. Background

1. In resolution GC(65)/RES/11.B.4, the General Conference encouraged the Secretariat to continue to foster regional and international collaboration and networking that expands access to research reactors, such as international user communities. It also encouraged the Secretariat to inform Member States considering the development or installation of their first research reactor of the issues related to utilization, cost-effectiveness, environmental protection, safety and security, nuclear liability, proliferation resistance, including the application of comprehensive safeguards, and waste management associated with such reactors, and, on request, to assist Member States in pursuing new reactor projects following the Agency-developed Specific Considerations and Milestones for a Research Reactor Project systematically and on the basis of a robust, utilization-based strategic plan.
2. The General Conference also urged the Secretariat to continue to provide guidance on all aspects of the research reactor life cycle, including the development of ageing management programmes at both new and older research reactors, to ensure continuous improvements in safety and reliability, sustainable long-term operation, the sustainability of fuel supply, exploration of efficient and effective disposition options for spent fuel and waste management, and the development of a knowledgeable customer capability in Member States decommissioning research reactors.
3. Furthermore, the General Conference encouraged the Secretariat to further strengthen its efforts to support capacity building based on research reactors, including with the IAEA Internet Reactor Laboratory project which could be expanded in the Asia-Pacific, Europe and Africa regions.
4. Finally, the General Conference called on the Secretariat to continue to support international programmes working to minimize the civilian use of highly enriched uranium (HEU) where such minimization is technically and economically feasible.
5. The General Conference, in resolution GC(65)/RES/11.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its sixty-sixth (2022) session.

## B. Progress Since the 65th Regular Session of the General Conference

6. To provide practical guidance on the application of *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), relevant Agency safety standards and other related guidelines, the Agency conducted a virtual Training Workshop on the Assessment of the National Nuclear Infrastructure to Support a New Research Reactor Project in December 2021, attended by 54 participants from 15 Member States. The workshop also provided a forum at which participants shared and discussed

experiences, challenges and lessons learned in the development and implementation of new research reactor projects.

7. The Agency held a Training Workshop on Technical Requirements in the Bidding Process for a New Research Reactor in Vienna in July 2022. The workshop aimed to provide the participating Member States with practical information on developing technical requirements for the bidding process for a new research reactor project, taking into account operation, utilization and safety requirements, and guidance on the criteria for bid evaluation. The workshop also provided a possibility to share Member States' experiences, challenges and lessons learned in the preparation and implementation of the bidding process for a new research reactor.

8. In October 2021, the Agency organized a virtual Technical Meeting on Risk Informed In-Service Inspections and Decision Making for Research Reactors with the attendance of 33 participants from 18 Member States. The participants shared their experience in planning and implementing the in-service inspections, discussed existing practices in probabilistic risk assessment for reliability and availability of research reactors, and concluded that the risk informed methodology may be feasible to a limited number of large size installations.

9. The Agency conducted a Training Workshop on Non-Destructive Examination, In-Service Inspection and Online Monitoring Techniques for research reactors in April 2022, in Vienna, attended by 22 participants from 15 Member States. In addition to lectures and discussions, the participants received hands-on training on in-service inspections at the TRIGA II reactor of the Vienna University of Technology.



*FIG. B.1. Hands-on training on in-service inspection at TRIGA II research reactor of the Vienna University of Technology*

10. To foster regional and international efforts in ensuring wide access to existing multipurpose research reactors and to increase research reactor operations and utilization, the Agency published *Considerations of Safety and Utilization of Subcritical Assemblies* (IAEA-TECDOC-1976). This publication was developed in view of the growing interest from Member States in subcritical assembly designs, safe operation and utilization programmes.

11. The Training Workshop on Expanding the Research Reactor Stakeholder Base through Strategic and Business Plans, held virtually in November 2021, contributed to the enhancement of research reactor utilization and sustainability by disseminating relevant methodologies, presenting success stories through illustrative examples, and sharing lessons learned, implementation strategies and good practices in strategic and business planning of these facilities.

12. In response to a request from the Chilean Nuclear Energy Commission for an Integrated Research Reactor Utilization Review (IRRUR) mission to the RECH-1 research reactor, a Consultancy Meeting on Utilization Review and Planning at Research Reactor RECH-1 was held virtually, owing to COVID-19 restrictions, in November 2021 to review the RECH-1 utilization documentation and planning, assess the current utilization of RECH-1, and provide advice on potential and constraints for utilization planning.

13. A virtual pre-IRRUR mission for Peru's RP-10 research reactor, located at the RACSO Nuclear Centre, took place in May 2022 upon the request of the Government of Peru. This preparatory mission allowed a better understanding of the utilization issues and challenges RP-10 is facing and defined further preparatory work and a detailed agenda for the full IRRUR mission scheduled later in 2022. The Technical Meeting on Preparation for Decommissioning for Research Reactors, held in July 2022 in Vienna, provided a forum to discuss Member States' experiences in consideration of ultimate decommissioning in the design and operation phases of research reactors, including management of the transition period between operation and decommissioning, and contributed to the development of an Agency publication on the topic.

14. The Agency conducted a Workshop on Dry Storage of Research Reactor Spent Fuel in November 2021 in Vienna with 55 participants from 28 Member States. The workshop provided guidance on the safe storage of spent research reactor fuel for extended periods in both wet and dry conditions, as well as on the transition from wet to dry storage, including several approaches to dry storage and the transition.

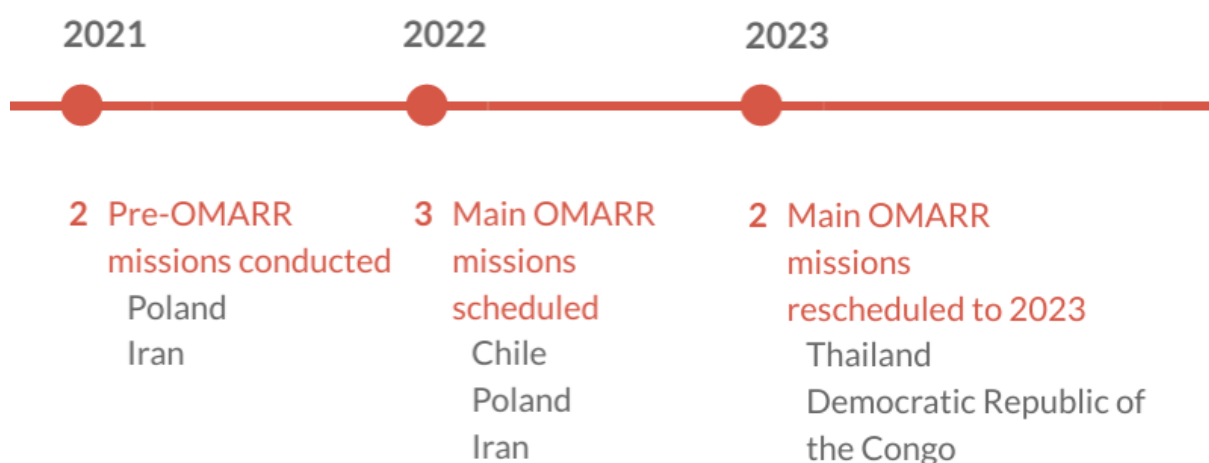
15. The Agency published *Research Reactor Spent Fuel Management: Options and Support to Decision Making* (IAEA Nuclear Energy Series No. NF-T-3.9) in December 2021, which provides a review of research reactor spent fuel management strategies and a methodology for selecting the preferred option. A set of decision support tools developed to consider economic and non-economic factors that might influence the selection is available for download as supplementary files on the publication's web page. A virtual introductory workshop on using these tools was held in July 2022 in preparation for the pilot national workshop on the topic later in 2022.

16. In September 2021, *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) was published, providing a detailed analysis of decommissioning costs for 20 research reactors, with diverse designs and located in a range of countries, as well as guidance for estimating uncertainties and contingencies. It also addresses the use of the Cost Estimation for Research Reactors in Excel software code, developed by the Agency to enable non-specialist users to develop preliminary cost estimates for decommissioning.

17. The Agency conducted an Integrated Nuclear Infrastructure Review for Research Reactors mission in Thailand in November–December 2021. The mission assisted Thailand in evaluating the status of the national nuclear infrastructure necessary to support its programme, which includes two new research reactor projects, and identifying further development needs to reach the respective milestones, and provided recommendations and suggestions that can be used by the counterparts in Thailand to address areas needing further actions.

18. The Agency conducted pre-Operation and Maintenance Assessment for Research Reactors (pre-OMARR) missions to Poland in February 2022 and the Islamic Republic of Iran in May 2022. OMARR missions were held in Chile in July 2022, and is scheduled in Poland in August 2022, and the Islamic Republic of Iran in September 2022. OMARR missions to the Democratic Republic of the Congo and Thailand were rescheduled to 2023.

### Operation and Maintenance Assessment for Research Reactors Missions



19. To foster regional and international efforts in ensuring wide access to existing multipurpose research reactors, the Agency re-designated the Research Institute of Atomic Reactors in the Russian Federation as an IAEA-designated International Centre based on Research Reactor (ICERR) for 2022–2025. The Agency mission to evaluate the request for designation of Morocco's National Centre for Nuclear Energy, Science and Technology (CNESTEN) as an ICERR was held in July 2022.

20. The 16th Research Reactor Group Fellowship training course, originally planned in cooperation with the Eastern European Research Reactor Initiative in 2020 and postponed due to the COVID-19 pandemic, was hosted by universities in Austria and Hungary in October–November 2021, with virtual participation of co-hosts from Czech Republic and Slovenia.

21. Internet Reactor Laboratories (IRLs) hosted by research reactors in Czech Republic and the Republic of Korea performed transmissions for their guest universities in Azerbaijan, Belarus, Mongolia, the Philippines and Tunisia.

22. Successful test connections were implemented between the IRL host research reactor MA-R1 at CNESTEN, Morocco, and Kenyatta University, Kenya. Regular transmissions of experiments will start later in 2022.
23. The Agency continued supporting projects related to the disposition of irradiated HEU fuel from the IVG.1M and IGR research reactors in Kazakhstan through consultancy meetings, the engagement of experts and contractual arrangements.
24. The Technical Meeting on the Conversion of Miniature Neutron Source Reactors from High Enriched Uranium to Low Enriched Uranium Fuel was held in Vienna in November 2021, with 25 participants from nine Member States. The meeting shared lessons learned in the conversion of miniature neutron source reactors (MNSRs) to low enriched uranium (LEU) fuel and in the repatriation of HEU MNSR fuel, and reviewed the potential for conversion of the remaining MNSR research reactors.
25. The Technical Meeting on the Management of Irradiated Uranium Waste from Molybdenum-99 Production Using Low Enriched Uranium Targets was held in Vienna in April 2022, with 67 participants from 22 Member States, who discussed existing practices, technical advances and plans for the management of irradiated uranium residues and waste to address the issue of growing uranium waste inventories resulting from the production of the most demanded medical radioisotope, molybdenum-99.
26. In March 2022, the Agency issued *Benchmarks of Fuel Burnup and Material Activation Computational Tools Against Experimental Data for Research Reactors* (IAEA-TECDOC-1992), which provides the consolidated results of the completed coordinated research project on the topic.





# Operating Nuclear Power Plants

## A. Background

1. In resolution GC(65)/RES/11.B.5, the General Conference requested the Secretariat to promote collaboration among interested Member States for strengthening excellence for the safe, secure, efficient, and sustainable operation of nuclear power plants, and to continue its support to interested Member States, in particular through strengthening their knowledge, experience, and capacity in management of ageing and plant life management.
2. The General Conference also encouraged the Secretariat to identify best practices and lessons learned with respect to procurement, supply chain, engineering, and related issues in the delivery of large, capital-intensive nuclear engineering projects and to promote and disseminate them through publications and web-based tools with respect to supply chain management.
3. Furthermore, the General Conference recognized the need to enhance further the support for grid and nuclear power plant interfaces, grid reliability, and cooling water usage, and recommended that the Secretariat collaborate on these matters with Member States that have operating nuclear power plants.
4. The General Conference, in resolution GC(65)/RES/11.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its sixty-sixth (2022) session.

## B. Progress Since the 65th Regular Session of the General Conference

5. The Agency co-hosted the second Global Forum for Nuclear Innovation in July 2022, in partnership with the US Electric Power Research Institute, the UK National Nuclear Laboratory, and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development, to improve the economic sustainability of the fleet of operating nuclear power plants (NPPs). This event is complemented by an Agency network on the same topic, created as a platform to support engagement between forum events.
6. In July 2022, the Agency published *Fuel Failure in Normal Operation of Water Reactors: Experience, Causes and Mitigation: Proceedings of a Technical Meeting* (IAEA-TECDOC-2004), compiling the information gathered during an IAEA Technical Meeting held virtually in December 2020, on fuel failures during normal operation; detection, management and monitoring of fuel failures; the impact of plant operation on failures and degradation, and possible mitigation actions by plant operation; the mitigation of failures by design and manufacturing; post-irradiation examinations, experimental studies and modelling of leaking fuel behaviour.
7. The draft publication *Sustaining Operational Excellence at Nuclear Power Plants — Principles and Challenges* (IAEA Nuclear Energy Series No. NR-G- 3.1) is now available in the IAEA Preprint

Repository. This publication provides nuclear industry leaders with a set of guiding principles for sustaining operational excellence under challenging business situations through the effective operation and management of NPPs.

8. In December 2021, the Agency organized a Technical Meeting on Enhancing Institutional Strength in Depth in the Nuclear Industry and a Consultancy Meeting on Institutional Strength in Depth in the Nuclear Industry to Sustain Operational Excellence. The meetings provided a venue for Member States with operating (or soon-to-be operating) NPP experience to share good practices and lessons learned in developing and achieving institutional strength in depth in the nuclear industry to sustain operational excellence. In total, 35 participants from 16 Member States, two international organizations and the European Commission engaged actively in the events.

9. In November 2021, the Agency organized a Technical Meeting on Effective Work Management Processes for Nuclear Power Plants, at which 12 participants from seven Member States discussed, shared and identified best practices and possible development targets related to work management processes to improve effectiveness. Optimizations within this scope will contribute to operational excellence and the overarching objective of improved facility economics.

10. In April 2022, the Agency organized a Technical Meeting on Excellence in Nuclear Power Plant Maintenance and Good Practices — Lessons Learned, at which 24 participants from 12 Member States shared experiences and outcomes in NPP maintenance processes, practices and procedures.

11. The Agency organized the 2021 Nuclear Operators' Forum, as an online event during the 65th regular session of the General Conference, dedicated to organizational excellence and leadership for the sustainability of operating nuclear power plants, where a panel of senior nuclear managers highlighted the importance of leadership leading towards technical and human excellence and the value of employee empowerment.

12. The Agency organized a joint event with FORATOM entitled “Management Systems for a Sustainable Nuclear Supply Chain” in September 2021 as a virtual event with about 100 participants from 23 Member States. During the meeting the participants exchanged experiences, practical examples, standard development news, new insights and case studies related to supply chain and management systems within the nuclear industry.

13. In June 2022, the Agency organized the Technical Meeting on Ensuring Operator Preparedness for the Transition from Operation to Decommissioning in Vienna, at which 42 participants from 24 Member States and two international organizations discussed the main challenges and issues of the transition period, and identified some solutions and good practices. Preparations started for the International Workshop on Managing the Transition from Operation to Decommissioning, to be held in December 2022, in Vienna.

14. The draft publication *Management of Ageing and Obsolescence of Nuclear Instrumentation and Control Systems and Equipment in Nuclear Power Plants and Related Facilities Through Modernization* (IAEA Nuclear Energy Series No. NR-T-3.34) was made available in the IAEA Preprint Repository. This publication will assist Member States in developing strategies to address ageing and obsolescence issues for instrumentation and control (I&C) systems by providing details on modernization considerations and information from relevant recent operator experience.

15. The draft publication *Introduction to Systems Engineering for the Instrumentation and Control of Nuclear Facilities* (IAEA Nuclear Energy Series No. NR-T-2.14) was also made available in the IAEA Preprint Repository. The publication provides an overview of the current knowledge, up to date best practices, experiences, benefits and challenges related to systems engineering. The publication is intended to be used by Member States to support the introduction of the systems engineering

methodology for all stakeholders involved in the engineering lifecycle of safety significant I&C for NPPs and to discuss how these activities can support the safe, reliable and long term operation of NPPs.

16. In October 2021, the Agency published the Chinese version of *Review of Fuel Failures in Water Cooled Reactors (2006–2015)* (IAEA Nuclear Energy Series No. NF-T-2.5, published in English in November 2019), which was further published in Arabic in May 2022, and in Russian in June 2022. The publication came as an effort to support interested Member States in their activities to improve the safe, secure and economical operation of existing NPPs throughout their operational lifetime,

17. The Agency published *Thermal Performance Monitoring and Optimization in Nuclear Power Plants: Experience and Lessons Learned* (IAEA-TECDOC-1971) in August 2021. Rising operating costs and increased competition have focused attention on the need to improve thermal performance in NPPs to ensure efficient electricity generation. This publication provides various methodologies for tracking and trending NPP thermal performance. It describes the essential elements of a thermal performance programme, providing guidelines on the design of the balance of the plant systems for new build NPPs and improvements to existing programmes for operating NPPs.

18. The Agency also published *Foreign Material Management in Nuclear Power Plants and Projects* (IAEA-TECDOC-1970) in August 2021. This publication addresses relevant aspects of foreign material management for NPPs, including the roles of all stakeholders at various stages during the lifetime of an NPP. The report shares knowledge on challenges, solutions and good practices based on operating experience. Providing a set of descriptive processes that integrate safety, performance and economic aspects of foreign material management, the publication supports efforts to eliminate or minimize foreign material related incidents, and to ensure reliable and efficient operation and maintenance of NPPs.

19. The Agency continues to support Member States in their human resources development for in-service inspection and pre-service inspection of their NPPs. Practical Arrangements between the Agency and Pakistan's National Centre for Non-Destructive Testing on cooperation in the area of non-destruction testing and structural integrity were signed in September 2021 to share Pakistan's experience with other Member States through publications, training courses, expert missions and placements as fellows/scientific visitors.

20. A Technical Meeting on the Life Management and Modernization of Fuel Fabrication and Fuel Reprocessing Facilities is scheduled for August 2022 to exchange technical information on challenges, lessons learned and best practices related to the life management and modernization of fuel fabrication and fuel reprocessing facilities.

21. The Agency published *Human Factors Engineering Aspects of Instrumentation and Control System Design* (IAEA Nuclear Energy Series No. NR-T-2.12) in 2021. Safety, reliability, and productivity in the nuclear industry result from a systematic consideration of human performance. The focus of this publication is to integrate knowledge from the disciplines of human factors engineering (HFE) and I&C to emphasize an interdisciplinary approach for the design of better human–system interfaces and consequently improved human performance in NPPs. The practical information provided in this publication is intended to support Member States' capabilities to improve their approach to I&C through the consideration of HFE.

22. The electrical grid is one of the nineteen infrastructure areas for newcomer countries. The Agency organized several events to support Member States to enhance their grids and NPP interfaces. For example, the National Workshop on Integrating First Nuclear Units within Polish Power System assisted Poland in familiarizing itself with specificities of nuclear technology that have an influence on its integration within the power system and in learning from other Member States' experience. Another

example is the National Workshop on Electric Grid Reliability and Interface with Nuclear Power Plants, which helped the Philippines understand the administrative and technical requirements for the interface between the electrical grid and NPPs. An interregional training course on electrical grid considerations and interactions with the NPP is also in planning.

23. In efforts to identify best practices and lessons learned with respect to procurement, supply chain, engineering, and related issues in the delivery of large, capital-intensive nuclear engineering projects, in August 2021 over 55 participants attended the Technical Meeting on Recent Issues in Supply Chain Management, presenting and discussing topics such as the management of supply chains for sustainable and safe operations of NPPs, commercial grade items and obsolescence, localization, counterfeit, fraudulent and suspect items, and advanced manufacturing.

24. In February 2022, the Agency launched the Quality and Management Standards and Regulations Toolkit to support managers, suppliers, owners and regulators in navigating the engineering, quality and management related standards and regulations needed to ensure the safe construction and operation of nuclear facilities. The toolkits were used for a fully virtual Training Course on Supply Chain Management and Procurement, organized in cooperation with the State Atomic Energy Corporation “Rosatom” of the Russian Federation in October 2021, with 48 participants from 16 Member States. Another training course took place on the same topic in July 2022 in Vienna with 64 participants from 25 Member States.

25. The Agency organized a hybrid Technical Meeting on the Use of Commercial Grade Products and Services in Nuclear Power Plants in April 2022 with 46 participants from 20 Member States and four international or non-governmental organizations. During the meeting, the participants identified ways to enhance uses of commercial or industrial grade items in nuclear facility safety systems through cooperation between operators, suppliers and regulators.

26. The Agency continued to produce and host nuclear supply chain advanced webinars to Member States on topics such as commercial grade items, impact of COVID-19 on the supply chain, remote and hybrid verifications, audits and inspections and the graded approach.

27. In December 2021, the Agency organized the annual Training Workshop on the Development of Severe Accident Management Guidelines Using the IAEA’s Severe Accident Management Guideline Development Toolkit. The workshop was attended by 73 participants from 26 Member States. The participants appreciated the work done by the Agency in providing a broad forum and discussion platform for severe accident management programmes and severe accident management guidelines development involving representatives from the Pressurized Water Reactor, Boiling Water Reactor and CANDU Owners Groups.

28. The Agency held the Interregional Training Course on Human Resource Development in September 2021, in Moscow, attended by 11 participants from seven countries. The event offered both didactic and applied content to address workforce planning and the human resource related needs and challenges across the nuclear power programme development. The second part of a two-part programme, this week-long event forged new networks among Member States and strengthened the knowledge and skills of participants.

29. The Agency supported Member States in their systematic approach to training application efforts by conducting interregional training courses and topical webinars. The systematic approach continued to be covered in a number of broader Agency activities including training courses, schools and peer reviews, including Safety Aspects of Long Term Operation missions in Bulgaria and Slovenia.

30. In October 2021, the Agency organized the Technical Meeting on Human Resource Development for Nuclear Power Programmes with 47 participants from 17 countries. The participants discussed the

current trends and modelling practices in human resources, coping with organizational changes and demographics, and the benefits of integration with leadership development, management functions, and diversity and integration.

31. The draft publication “*Human Resource Management for New Nuclear Power Programmes*” (IAEA Nuclear Energy Series No. NG-T-3.10 (Rev. 1)) was made available in the IAEA Preprint Repository. This publication aims to provide Member States with a structured approach to developing an effective human resource management strategy, which can be adapted to suit the nature and scope of a national programme. In each phase of the Milestones approach, the publication identifies the required actions related to these issues, and presents observations and lessons learned from Member States.



# Agency Activities in the Development of Innovative Nuclear Power Technology

## A. Background

1. In resolution GC(65)/RES/11.B.6, the General Conference requested the Secretariat to promote collaboration among interested Member States in developing innovative, globally sustainable nuclear energy systems and to support the establishment of effective collaboration mechanisms to exchange information on relevant experiences and good practices. It also encouraged the Secretariat to consider further opportunities to develop and coordinate the services it provides in building long-term national nuclear energy strategies and in long-term sustainable nuclear energy deployment decision-making using, inter alia, the analytical approaches and tools developed by International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO).
2. The General Conference also encouraged the Secretariat to study cooperative approaches to the back end of the nuclear fuel cycle to ensure effective cooperation among countries towards the long-term sustainable use of nuclear energy and requested the Secretariat to facilitate discussion among developers of advanced reactors, small and medium sized or modular reactors (SMRs) and Generation IV reactors, on the challenges and technologies related to decommissioning and radioactive waste management at the earliest stage of their design thinking.
3. Furthermore, the General Conference encouraged the Secretariat to further its efforts on distance learning/training on development and evaluation of innovative nuclear technology for students and staff of universities and research centres, and to further develop tools supporting this activity that supports efficient delivery of services to Member States.
4. The General Conference, in resolution GC(65)/RES/11.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its sixty-sixth (2022) session.

## B. Progress Since the 65th Regular Session of the General Conference

5. The IAEA INPRO School on Methodology, Tools and Analysis for Enhanced Nuclear Energy Sustainability was held virtually in November 2021 and was attended by 37 participants from eight Member States. The purpose was to familiarize the participants with INPRO concepts, methodology and tools.
6. A Technical Meeting is scheduled in August 2022 to present and discuss results of the Analysis Support for Enhanced Nuclear Energy Sustainability (ASENES) study on sustainable deployment scenarios for SMRs with the aim of encouraging interested Member States to use methods and tools developed by the Agency for nuclear energy evolution scenario modelling, nuclear energy system



economic assessments, comparative evaluations of nuclear energy systems or scenario options, and road mapping, including the new service being developed by INPRO on ASENES.

7. In September 2021, 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 presents the outputs of the INPRO collaborative project ROADMAPS. and introduces the concept of roadmapping for enhanced nuclear energy sustainability, which has been developed over the course of several collaborative projects within INPRO.

8. To promote collaboration among interested Member States in developing innovative, globally sustainable nuclear energy systems and to support the establishment of effective collaboration mechanisms to exchange information on relevant experiences and good practices, the Agency launched a new coordinated research project (CRP) entitled Technical Evaluation and Optimization of Nuclear–Renewable Hybrid Energy Systems with over 20 participants from 19 Member States to technically evaluate and optimize the options for the coordinated use of nuclear and renewable energy.

9. The draft publication *Hybrid Energy Systems* (IAEA Nuclear Energy Series No. NR-T-1.24) was made available in the IAEA Preprint Repository. It summarizes the opportunities for nuclear–renewable hybrid energy systems that could be pursued in various Member States as a part of their future energy mix. In November 2021, a Joint Russia–IAEA INPRO School for Managers and Decision-Makers in the Nuclear Sector and Government was held virtually to promote further application of multi-criteria decision analysis methods for comparative evaluation of plausible nuclear energy system options by interested INPRO members to support decision analysis and prioritization in national nuclear energy programmes. The school was attended by 40 trainees from 14 Member States.

10. In November 2021, the 7th DEMO Programme Workshop, a platform to facilitate international collaboration on defining and coordinating demonstration fusion power plant (DEMO) programme activities, focused on identifying international practices on regulation of future nuclear fusion power plants, including aspects of safety and security, radioactive waste management, and considerations for safeguards. The event, held virtually, was attended by 80 participants from 14 Member States. To further discuss the classification of radioactive waste generated during the production of fusion energy and at the end of life after decommissioning, the Agency also organized a dedicated Workshop on Waste Management for Fusion. At the current stage of fusion progress, the development of a well-defined scheme in which radioactive waste is characterized and classified could provide clear guidelines for Member States and will help to advance the licensing process for future fusion demonstration and pilot power plants.

11. Last year, the Agency redesigned and published the 41st edition of *Nuclear Power Reactors in the World* (Reference Data Series No. 2), one of the Agency’s top annual publications, that included official 2020 nuclear power operating experience statistical reports. Also, the Agency released the 52nd edition of *Operating Experience with Nuclear Power Stations in Member States*, a series of annual reports on operating experience with nuclear power plants in Member States. The publication is a direct output from the Power Reactor Information System and contains information on electricity production and overall performance of individual plants during 2020. In addition to annual information, the publication contains a historical summary of performance during the lifetime of individual plants, figures illustrating worldwide performance of the nuclear industry, as well as design characteristics and dashboards of all operating nuclear power plants.

12. Over 450 participants from more than 50 countries gathered in November 2021 at the first Agency webinar on fusion commercialization entitled “*Pushing for Fusion Energy — What is happening now?*”, and discussed the status of fusion development, the existing challenges, and how the public and private

sector can collaborate to speed up the process of developing fusion as a reliable source of energy that is also commercially viable.

13. The Agency continued supporting information exchange and coordinating work on topics relevant to fusion science and technology through its series of periodic technical meetings, such as the 17th Technical Meeting on Energetic Particles and Theory of Plasma Instabilities in Magnetic Confinement Fusion, the 4th Technical Meeting on Fusion Data Processing, Validation and Analysis, and the 13th Technical Meeting on Plasma Control Systems, Data Management and Remote Experiments in Fusion Research. These events brought together more than 300 participants from 85 institutions representing 31 Member States.

14. In June 2022, the Agency held the Technical Meeting on Synergies between Nuclear Fusion Technology Developments and Advanced Nuclear Fission Technologies attended by 70 participants from 29 Member States. About 50 contributions were presented and discussed at the meeting, which will lead to the development of an IAEA Nuclear Energy Series publication on synergies in technology development between nuclear fission and fusion for energy production.

15. The Agency launched a new activity aimed at identifying and developing a basic framework to support the pre-feasibility study of a fusion demonstration plant for energy production. The goal of this inter-Departmental effort is to produce a set of relevant Agency publications addressing generic user requirements and criteria, technology-neutral safety requirements and basic infrastructure. Safety and licensing of fusion technologies will also be considered.

16. Preparations for the Technical Meeting on Decommissioning Considerations for Fusion Facilities, to be held in October 2022 by the Agency in collaboration with the French Alternative Energies and Atomic Energy Commission and the ITER Organization are under way.

17. The 19th INPRO Dialogue Forum on Enhancing Public Acceptance of Nuclear Energy through Institutional Innovations was held virtually in December 2021. It was attended by 87 participants from 31 Member States and seven international organizations.

18. In April 2022, Uzbekistan became a member of INPRO. Forty-three Member States plus the European Commission are currently INPRO members.

19. To further explore opportunities for synergy between the Agency's activities (including INPRO) and those pursued under other international initiatives in areas relating to international cooperation in peaceful uses of nuclear energy, safety, proliferation resistance and security issues, the Agency held a kick-off meeting in February–March 2022 to initiate a study on legal and institutional issues of prospective deployment of thermonuclear (fusion) facilities. The meeting, attended by six Member States as well as ITER representatives, led to the development of the terms of reference for the study.

20. The Agency published e-learning modules on water cooled reactor (WCR) technology development, on pressurized water reactors, on boiling water reactors, on pressurized heavy water reactors, on supercritical water reactors (SCWRs), on hybrid energy systems, and on natural circulation, and provided some of the modules in other United Nations languages via its the Cyber Learning Platform for Network Education and Training.



FIG. B.1. E-learning modules on advanced reactor technologies and hybrid energy systems

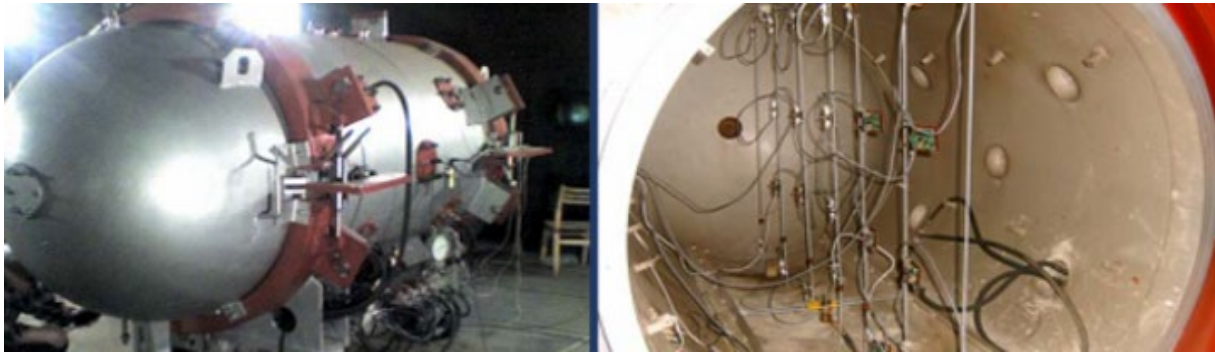
21. The Agency made available in the IAEA Preprint Repository *Nuclear Reactor Technology Assessment for Near Term Deployment* (IAEA Nuclear Energy Series No NP-T-1.10 (Rev. 1)), which provides refined comprehensive guidance on the use of the Agency's reactor technology assessment methodology. This revised publication implements the lessons learned during six years of application and incorporates and harmonizes new developments and experiences on SMRs, non-electric applications of nuclear power and hybrid energy systems into the methodology. The Agency developed an e-learning module entitled "Nuclear Reactor Technology Assessment for Near Term Deployment" based on the IAEA Nuclear Energy Series No NP-T-1.10 (Rev. 1) available in the IAEA Preprint Repository.

22. In August 2022, the Agency is launching a new platform called Hub for On-line Nuclear Power Plant Part-Task Simulators (HOPS) for learning/training about innovative nuclear technologies, including part-task simulators on various hybrid energy systems, a neutron diffusion equation solver, and training on passive autocatalytic recombiner performance.



FIG. B.2. HOPS platform: nuclear–renewable hybrid energy system part-task simulators

23. In Q3 2022, the Agency will launch the Simulation and Experimental Analyses Network Information System (SANIS), a new database that will collect information about numerical codes applicable to the simulation of severe accident progression in nuclear power plants, and information about experimental facilities worldwide that support the analysis of severe accident phenomena in nuclear power plants.

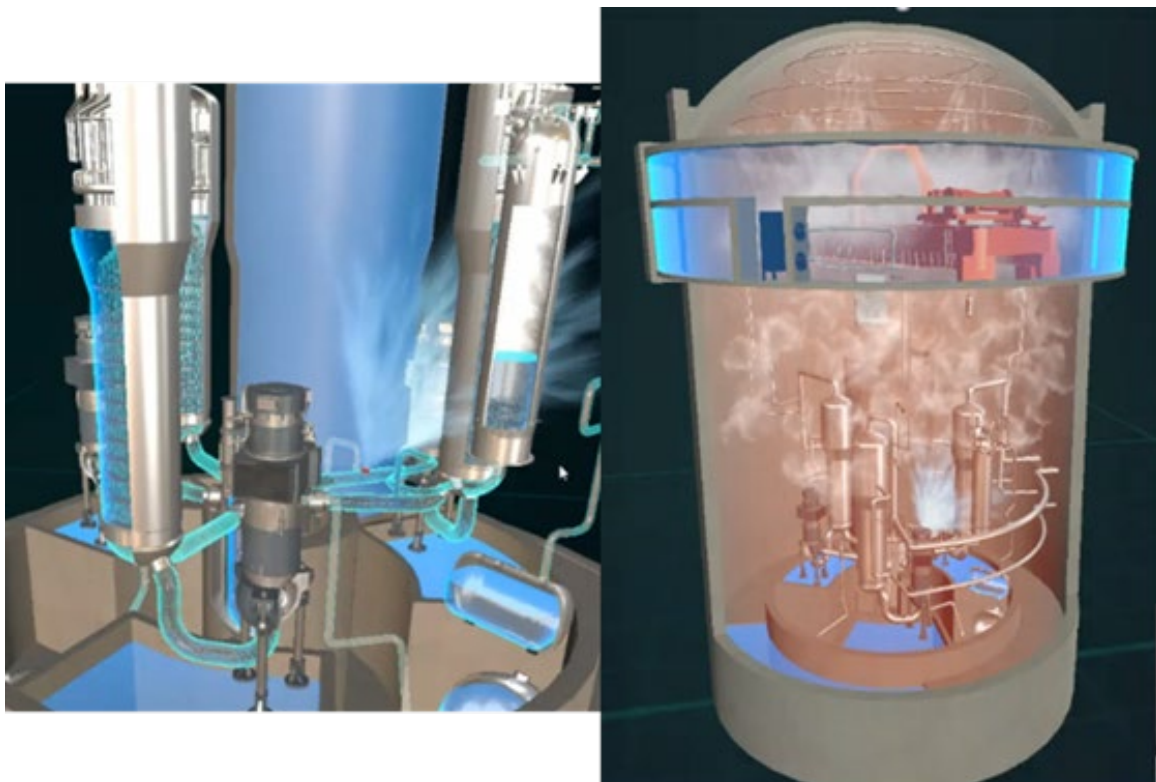


*FIG. B.3. Experimental facilities for studying severe accidents*

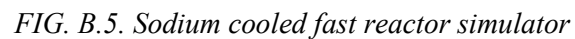
24. The Technical Meeting on Ex-Vessel Molten Corium Behaviour and Coolability was held virtually in June 2022 with 98 participants from 27 Member States with 27 contributions on technological and safety related aspects of ex-vessel molten corium behaviour and cooling in water cooled reactors.

25. In May 2022, the Agency conducted the Joint ICTP–IAEA Advanced School/Workshop on Computational Nuclear Science and Engineering, attended by 150 participants from 45 Member States.

26. In 2022, the Agency acquired and made available to its Member States educational simulators for a typical pool-type sodium cooled fast reactor and for severe accidents in WCRs, complementing the suite of the Agency’s basic principle simulators for education and training.



*FIG. B.4. Severe accident simulator*



28. To facilitate information exchange related to advancing reactor technology, the Agency published *Numerical Benchmarks for Multiphysics Simulation of Pressurized Heavy Water Reactor Transients* (IAEA-TECDOC-1994) and *Prediction of Transverse Creep Based on Operating Conditions and Microstructure of Heavy Water Reactor Pressure Tubes* (IAEA-TECDOC-2000).



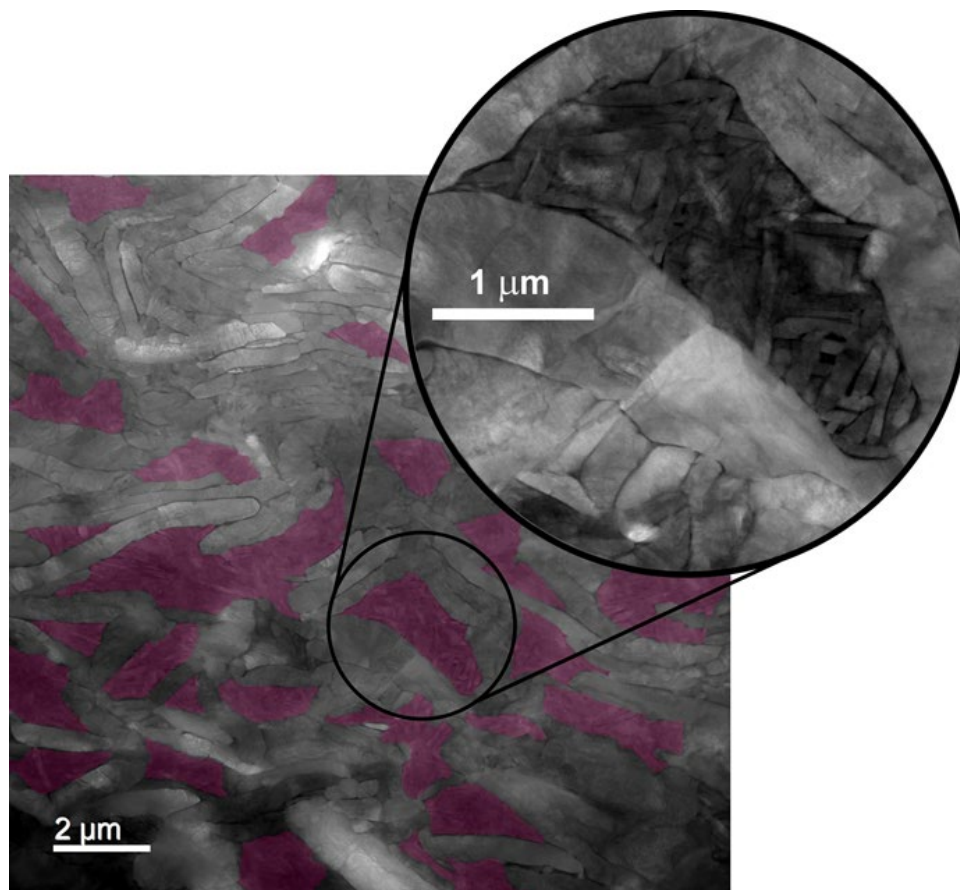


FIG. B.6. Scanning transmission electron microscopy image showing transformed  $\alpha$ -phase dispersed amongst the transformed  $\alpha$ -grains in the front end of a CANDU pressure tube

29. As the outcome of the CRP entitled “Methodology for Assessing Pipe Failure Rates in Advanced Water Cooled Reactors (WCRs)” conducted 2018–2021, the Agency published *Technical Insights from Benchmarking Different Methods for Predicting Pipe Failure Rates in Water Cooled Reactors* (IAEA-TECDOC-1988), and made *Methodologies for Assessing Pipe Failure Rates in Advanced Water Cooled Reactors* (IAEA Nuclear Energy Series No. NR-T-2.16) available in the IAEA Preprint Repository.



FIG. B.7. Double-ended guillotine break of feedwater line and ruptured feedwater pipe

30. In October 2021, the Agency organized a virtual Technical Meeting on Artificial Intelligence for Nuclear Technology and Applications, attended by over 200 participants from 60 Member States. A publication is being drafted and is scheduled to be published by the end of 2022.

31. A Technical Meeting on the Technical Challenges and Advances in Fuel Fabrication for Water Reactors: Recent Experience and Future Prospects was held virtually in November 2021. It was attended by 39 experts from 21 Member States, who exchanged information on recent experiences as well as ongoing and future improvements in water reactor fuel fabrication technology.

32. In April 2022, the Agency conducted in Vienna the International Conference on Fast Reactors and Related Fuel Cycles: Sustainable Clean Energy for the Future (FR22) attended by 680 participants. The Director General opened FR22 highlighting that, while the world faces the twin challenge of an energy crisis and climate crisis, it is time to focus again on the enduring appeal of fast reactors and related fuel cycles. FR22 stands not only for the development of next generation fast reactor systems, but also for the development of the next generation of scientists and engineers, and for promoting the participation of female professionals.



*FIG. B.8. Rafael Mariano Grossi, the Director General, in the opening of the International Conference on Fast Reactors and Related Fuel Cycles, the largest scientific event held at Headquarters in Vienna since the start of the pandemic.*

33. The Agency launched a new CRP entitled “Advancing Thermal-Hydraulic Models and Predictive Tools for Design of SCWR Prototypes” with 21 participants from 14 Member States. The CRP will support Member States in thermal-hydraulic modelling, tools development and experimental studies in furthering the design of SCWRs towards their prototyping.

34. The new membership of the Technical Working Group on Gas Cooled Reactors (TWG-GCR) for the period 2021–2024 was established. This TWG looks after a wide spectrum of publications in the pipeline related to modular high temperature gas cooled reactor technology developments, results of CRPs, the IAEA Nuclear Graphite Knowledge Base initiative, and education and training.

35. In 2022, the Agency launched a new CRP entitled “Benchmark of Transition from Forced to Natural Circulation Experiment with Heavy Liquid Metal Loop” with the goal of developing Member States’ advanced fast reactor analytical capabilities for simulation and design using system, computational fluid dynamic (CFD), and subchannel analysis codes. A total of 25 organizations from 11 Members States and one international organization submitted research proposals.



36. In June 2022, the Agency conducted a Technical Meeting on the Development and Application of Open-Source Modelling and Simulation Tools for Nuclear Reactors, attended by over 100 participants from 40 Member States. As an expected output, a Technical Reports Series publication on the state-of-the-art in open-source tools for reactor analysis will be published.

37. In November 2021, the Agency conducted a Workshop on High Temperature Gas Cooled Reactor Technology, attended by 107 participants from 23 Member States. The workshop was conducted as a follow up of the release the high temperature reactor code package for high temperature reactor safety performance analyses (HCP) from the Jülich Research Centre (FZJ) in Germany to the IAEA in 2020, with the purpose to enable more Member States to use this computer code to perform safety analysis of high temperature gas-cooled reactors (HTGRs).



# Approaches to Supporting Nuclear Power Infrastructure Development

## A. Background

5. In resolution GC(65)/RES/11.B.7, the General Conference encouraged the Nuclear Infrastructure Development Section to pursue its activities integrating the Agency's assistance provided to Member States embarking on or expanding nuclear power programmes, and encouraged Member States interested in or embarking on new or expanded nuclear power programmes to make use of Agency services related to nuclear infrastructure development.

6. The General Conference also requested the Secretariat to continue to incorporate lessons learned from Integrated Nuclear Infrastructure Review (INIR) missions and to enhance the effectiveness of such INIR activities, urged Member States to develop and keep updated action plans to address the recommendations and suggestions provided by the INIR missions, and encouraged them to participate in the development of their Member State-specific Integrated Work Plans (IWPs).

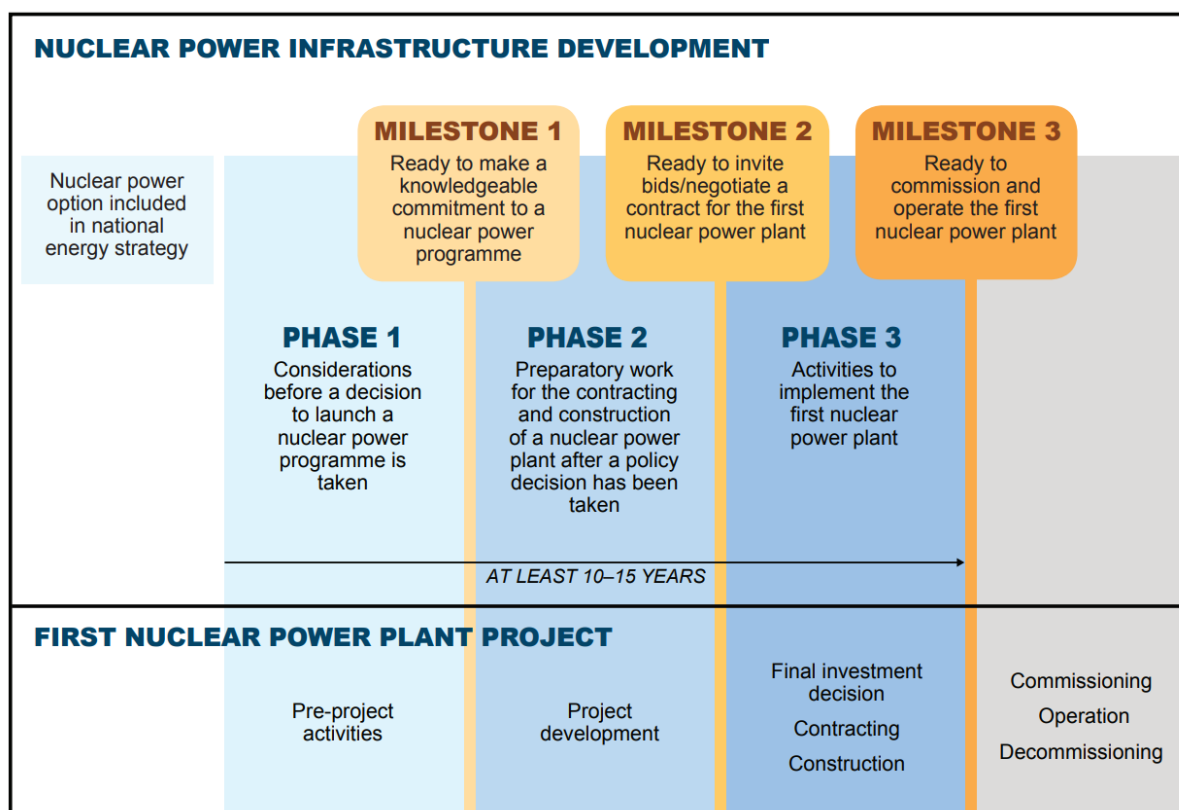
7. The General Conference also encouraged the Secretariat to facilitate, where possible, international coordination to improve efficiency of multilateral and bilateral assistance to these Member States, and encouraged the strengthening of activities undertaken by Member States, both individually and collectively, to cooperate on a voluntary basis in nuclear infrastructure development.

8. The General Conference, in resolution GC(65)/RES/11.B.9, requested the Director General to report on progress made in the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its sixty-sixth (2022) session.

## B. Progress Since the 65th Regular Session of the General Conference

5. The Agency continued to underline the importance of an appropriate legal framework as well as an effective and independent regulatory framework and body in nuclear power programme development. The legal framework and regulatory framework are two of the 19 infrastructure issues in the Milestones approach. In this regard, *Experiences of Member States in Building a Regulatory Framework for the Oversight of New Nuclear Power Plants: Country Case Studies* (IAEA-TECDOC-1948) was published in 2021.

6. The Milestones approach continues to be the leading programmatic guide for Member States embarking on or expanding existing nuclear power programmes. In an effort to ensure its continued applicability, the Agency initiated the revision of the IAEA Nuclear Energy Series publication NG-G-3.1 (Rev. 1) to incorporate lessons learned from Member States using the Milestones approach, present the main findings of INIR missions, address the needs of expanding countries, as well as infrastructure considerations for SMRs. A virtual Technical Meeting to present and receive feedback on the first draft was held in October 2021 with the participation of 57 nominees from 34 Member States.



7. The Agency organized a workshop on the procurement of services to support Egypt's nuclear power programme development. Participants were trained via a virtual, national workshop conducted in June 2021 on procurement management, roles and responsibilities, and specific procurement services required during construction, commissioning, operation and maintenance phases for a nuclear power plant (NPP).

8. The Agency made the draft publication *Integrated Life Cycle Risk Management for New Nuclear Power Plants* (IAEA Nuclear Energy Series No. NR-T-2.15) available in the IAEA Preprint Repository. This publication is particularly important during the preparation and construction phases of an NPP as it anticipates the risks that could arise during the operation and decommissioning phases. This publication is designed to enhance stakeholders' understanding of the fundamental processes, procedures, and methods for integrated risk management.

9. A registry containing all recommendations and suggestions made during previous missions is maintained and updated regularly. Lessons learned are further incorporated into revisions of existing publications and the development of new publications related to nuclear infrastructure development, in particular *Integrated Nuclear Infrastructure Review (INIR): Ten Years of Lessons Learned* (IAEA-TECDOC-1947), which was published in 2021, as well as the current revision of the Milestones approach.

10. The Secretariat continued to perform INIR missions, where appropriate, in a mixture of English and one of the United Nations official languages to facilitate the highest level of information exchange. Whereas self-evaluation reports are expected to be submitted in English, supporting documents can be provided in one of the other United Nations official languages. The main INIR mission report is published in English.

11. Through regular training of external experts and staff members from relevant Departments, most recently in October 2021, the continued sustainability of the INIR service and the availability of a broad

pool of experts is being ensured. The Secretariat continued to ensure that the use of external experts for INIR missions did not constitute a conflict of interest or provide a commercial advantage.

12. Additionally, to meet growing recognition and use of *Milestones in the Development of a National Infrastructure for Nuclear Power* (IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1)), the publication was translated and published in Arabic, French, Russian, and most recently Chinese and Spanish (2021).

13. The Agency published *Case Studies on the Development of a Comprehensive Report to Support the Decision Making Process for a Nuclear Power Programme* (IAEA-TECDOC-1993) in 2022 that intends to support Member States that are developing comprehensive reports by sharing the experience of the ones that have already completed this process or are well advanced on this path.

14. The draft publication *Managing Siting Activities for Nuclear Power Plants* (IAEA Nuclear Energy Series No. NG-T-3.7 (Rev. 1)) was published in the IAEA Preprint Repository in 2021. The publication is intended to help Member States ensure that appropriate sites for an NPP are identified, assessed and licensed, in a well planned and efficient manner, taking into account all relevant factors and lessons learned from recent events.

15. The revision of *Milestones in the Development of a National Infrastructure for Nuclear Power* (IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1)) is ongoing and a Technical Meeting on the Milestones Approach in the Development of a National Infrastructure for Nuclear Power was held in October 2021, with 57 participants from 34 Member States, to receive feedback and input into the first draft.

16. The revision of *Preparation of a Feasibility Study for New Nuclear Power Projects* (IAEA Nuclear Energy Series No. NG-T-3.3) is also ongoing and a Technical Meeting, held in April 2022, provided 53 participants from 26 Member States with the opportunity to review and comment on all chapters of the draft.

17. The revision of *Managing Environmental Impact Assessment for Construction and Operation in New Nuclear Power Programmes* (IAEA Nuclear Energy Series No. NG-T-3.11) is ongoing and a related Technical Meeting on the Consideration of Environmental Protection in New Nuclear Power Programmes was held in October 2021 with 81 participants from 30 Member States.

18. To review and adapt the application of the evaluation methodologies and guidelines for SMRs, taking into account the work done under the SMR Regulators' Forum and the Agency's activities on SMRs, the Agency reviewed and confirmed the applicability of the Milestones approach and of the conditions in *Evaluation of the Status of National Nuclear Infrastructure Development* (IAEA Nuclear Energy Series NG-T-3.2 (Rev. 1)). The outcomes and guidance materials developed by the SMR Regulators' Forum and other Agency activities will be taken into account in the revision of the Milestones approach.

19. An annual meeting with Member States providing financial support and expertise for training courses was organized for this purpose in October 2021, during which a White Paper on the continuation of the project on Supporting Member States Considering or Planning to Introduce or Expand Nuclear Power Programmes in Developing the Sustainable National Infrastructure Required for a Safe, Secure and Peaceful Nuclear Power Programme and a calendar of proposed training events on Integrated Nuclear Infrastructure Training for 2021–2022 were discussed in the light of delayed implementation of activities due to COVID-19.

20. The Agency organized three webinars in the series "Governing New Nuclear Programmes: Newcomer Success Stories" entitled "A Decade of IAEA Integrated Support to Embarking Countries" in September 2021, "Newcomers Success Stories: Belarus" in November 2021 and "Good Practices and

Common Issues Identified through INIR in the Development of Nuclear Power Programmes” in June 2022. Approximately 760 participants from 60 countries attended the three webinars.

# Small and Medium Sized or Modular Reactors — Development and Deployment

## A. Background

1. In resolution GC(65)/RES/11.B.8, the General Conference encouraged the Secretariat to continue consultations and interactions with interested Member States, the competent organizations of the United Nations system, financial institutions, regional development bodies, and other relevant organizations regarding advice on the development and deployment of small and medium sized or modular reactors (SMRs). It also encouraged the Secretariat to continue working on defining indicators of safety performance, operability, maintainability, and constructability so as to assist countries in assessing advanced SMR technologies, and developing guidance for SMR technology implementation.
2. The General Conference called upon the Secretariat to continue to promote effective international exchange of information on options as regards SMRs available internationally and invited the Secretariat and Member States that are in a position to offer SMRs to foster international cooperation in undertaking studies of the social and economic impacts of SMR deployment in developing countries, their potential integration with renewables, and their non-electric applications.
3. The General Conference, in resolution GC(65)/RES/11.B.9, requested the Director General to report on the implementation of this resolution to the Board of Governors as appropriate and to the General Conference at its sixty-sixth (2022) session.

## B. Progress Since the 65th Regular Session of the General Conference

4. The Agency has in recent years intensified its work in providing support to Member States in the development and deployment of SMRs. In 2021, it established the [Agency-wide Platform on SMRs and their Applications](#) providing a ‘one-stop-shop’ for Member States and other stakeholders interested in the development and deployment of the SMR technology.
5. Within this framework, the Agency organized a side event during the 65th regular session of the General Conference in September 2021 to present the platform and discuss the global development and deployment status of SMRs.
6. The platform is an internal governance mechanism, and the platform implementation team and Steering Committee met frequently to work on the assigned tasks through the terms of reference, as well as to address requests made by Member States -.



7. The Agency developed an SMR medium term strategy for 2022–2029, which defines seven strategic objectives designed to ensure timely, relevant, and consistent Agency contributions to address the needs and gaps identified in an environmental scan.
8. A booklet entitled *Small Modular Reactors: A New Nuclear Energy Paradigm* targeted at policymakers and government officials interested in SMRs was prepared for the 66th General Conference to provide key stakeholders in Member States with the summary of enabling factors to be considered when deciding and deploying SMRs. The booklet covers global perspectives, potential benefits and challenges, factors enabling the development and drivers leading to wide-scale commercial deployment of SMRs, with special emphasis on SMRs for near-term deployment.
9. The Agency organized a side event during the International Conference on Nuclear Law: The Global Debate in April 2022, highlighting the work of the platform as well as discussing the legal frameworks for emerging small modular reactor technologies. This hybrid event was attended by over 50 in-person and 150 online participants. The Agency also published a brochure to provide concise and clear information about the SMR platform.
10. The Agency completed an SMR coordination and resource portal to provide Member States with a comprehensive and systematic overview of all the Agency's services and activities on SMRs and their applications and launched the first version in July 2022.
11. The Agency launched a new four-year interregional technical cooperation project to support Member States' capacity building on small modular reactors and microreactors and their technology and applications.
12. The Agency organized a virtual course on small modular reactors in April 2022, at the request of the Brazilian Association for the Development of Nuclear Activities, during the 2022 Nuclear Summit held in Brazil.
13. Four task forces were created within the SMR platform to address Member States' requests in the areas of unified design of small modular reactors in relation to external events and their site-independent design; considerations to facilitate the accelerated deployment of SMRs and microreactors; the consolidation of Agency activities in the area of transportable/floating nuclear power plants; and to conduct an expert mission to support the pre-feasibility study of small modular reactor deployment in Jordan.
14. Under direct guidance and supervision of the IAEA Director General, the Agency launched the Nuclear Harmonization and Standardization Initiative (NHSI) with the goal of facilitating the safe and secure deployment of SMRs and other advanced nuclear reactors. This major new initiative brings together an array of stakeholders including regulators, vendors, technology holders, operators and international organizations and associations. Harmonization of regulatory and standardization of industrial approaches to SMRs are the expected outcomes of NHSI and shall thus support maximizing SMRs contribution to achieving the goals of Agenda 2030 and the Paris Agreement, including reaching net zero carbon emissions by 2050. To coordinate the overall effort, a special task force was created within the IAEA Platform on SMR and their applications. The kick-off meeting of NHSI took place in Vienna in June 2022.



*FIG. B.1. Rafael Mariano Grossi, IAEA Director-General, delivers his opening remarks at the Nuclear Harmonization Standardization Initiative (NHSI) Kick-off meeting held at the Agency headquarters in Vienna, Austria. 23 June 2022*

15. To promote the effective international exchange of information on SMR options, a Technical Meeting on the Design, Fabrication and Irradiation Behaviour of Small Modular Reactor Fuels was held virtually in October 2021. It was attended by 45 experts from 19 Member States and two international organizations, who exchanged information on recent experiences as well as ongoing and future improvements in the design, fabrication and irradiation behaviour of water cooled SMR fuels, molten salt SMR fuels, and high temperature gas cooled SMR fuels. It also comprised a special forum on national regulators' and technical support organizations' perspectives on the licensing of advanced fuels for light water reactors.

16. The Agency prepared the 2022 edition of the booklet entitled *Advances in Small Modular Reactor Technology Developments: A Supplement to IAEA Advanced Reactors Information System (ARIS)*, to be published for the General Conference 66th session to be held in September 2022

17. In November 2021, the Agency convened the Workshop on High Temperature Gas Cooled Reactor Technology following the release of the code package for high temperature reactor safety performance analyses from the Jülich Research Centre to the Agency. Conducted virtually, the workshop attracted 107 participants from 23 Member States and one international organization.

18. In November 2021, the Agency held the annual Technical Meeting on the Status of the IAEA Nuclear Graphite Knowledge Base attended by 15 participants from 11 Member States. This knowledge base, established in 1999, seeks to preserve and expand scientific information on the physical, chemical, mechanical and other properties of nuclear graphite relevant for nuclear power and nuclear safety. This is a key activity to support technology development of modular high temperature gas cooled SMRs.



*FIG. B.2. IAEA Nuclear Graphite Knowledge Base*

19. In February 2022, the Agency organized a two-day webinar entitled “Atoms for Space: Nuclear Systems for Space Exploration”, attended by 505 participants from 66 Member States. The purpose of the webinar was to present the status of development of nuclear systems for space exploration and outline some future prospects in this area. Different systems were presented: nuclear power systems that convert heat generated by decay of radioisotopes into electricity or produce power from a reactor; nuclear propulsion systems, i.e. propulsion systems that use energy generated from nuclear fission or fusion to provide thrust to a spacecraft; surface power systems intended to provide extra-terrestrial surface power for extended exploration missions and a possible sustained human presence on other planetary bodies.



*FIG. B.3. The Agency held a two-day webinar entitled “Atoms for Space: Nuclear Systems for Space Exploration” in February 2022*

20. To foster international cooperation in undertaking studies of the social and economic impacts of SMR deployment in developing countries, their potential integration with renewables, and their non-electric applications, the Agency organized the Technical Meeting on Developing a Road Map for the Commercial Deployment of Nuclear Hydrogen Production in April 2022, attended by 50 participants from 29 Member States and four international organizations. The production of hydrogen, including from high temperature processes, is seen as an important non-electric application of SMRs.



*FIG. B.4. Hydrogen energy stock. Several countries are looking to nuclear processes to generate low-carbon hydrogen on a massive and cost-competitive scale (Photo: Shutterstock)*

21. The Agency launched a new coordinated research project entitled “Technologies Enhancing the Competitiveness and Early Deployment of Small Modular Reactors” for 2022–2025 to develop a methodology, identify enabling generic technologies, and identify gaps and opportunities.

22. In May 2022, the Agency organized a Technical Meeting on Codes and Standards, Design Engineering and Manufacturing of Components for Small Modular Reactors, attended by 85 participants from 28 Member States and four international organizations, to foster further activities on defining indicators of safety performance, operability, maintainability, and constructability so as to assist countries in assessing advanced SMR technologies, and on developing guidance for SMR technology implementation. The challenges, needs and gaps identified in will directly support the industrial track of the NHSI.

23. The new membership of the Technical Working Group on Small and Medium Sized or Modular Reactors (TWG-SMR) for the period 2022-2025 was established. The TWG-SMR has three topical sub-groups on the development of generic user requirements and criteria for SMR technology; on research, technology development and innovation, codes and standards; and on industrialization, design engineering, testing, manufacturing, supply chains, and construction technology.

24. The Agency published *Technology Roadmap for Small Modular Reactor Deployment* (IAEA Nuclear Energy Series No. NR-T-1.18), which provides Member States with a set of generic roadmaps that can be used in the deployment of SMRs based on the latest inputs from Member States. The publication emphasizes the activities of owners/operating organizations that drive the demand and



requirements for reactor designs, the designers, who develop the technologies, and regulators, who establish and maintain the regulatory requirements. It also provides a methodology for developing a technology roadmap for reactors with longer development horizons, and provides information on emerging opportunities and challenges for this relatively new nuclear technology.

25. After the first Technical Meeting held in May 2021, which identified specific requirements and criteria associated with SMR technologies for various energy market niches, in August 2022 the Agency scheduled a second Technical Meeting on Generic User Requirements and Criteria of Small Modular Reactor Technologies for Near Term Deployment, to be held in the framework of the NHSI, to agree on the structure and content of an Agency guidance publication.

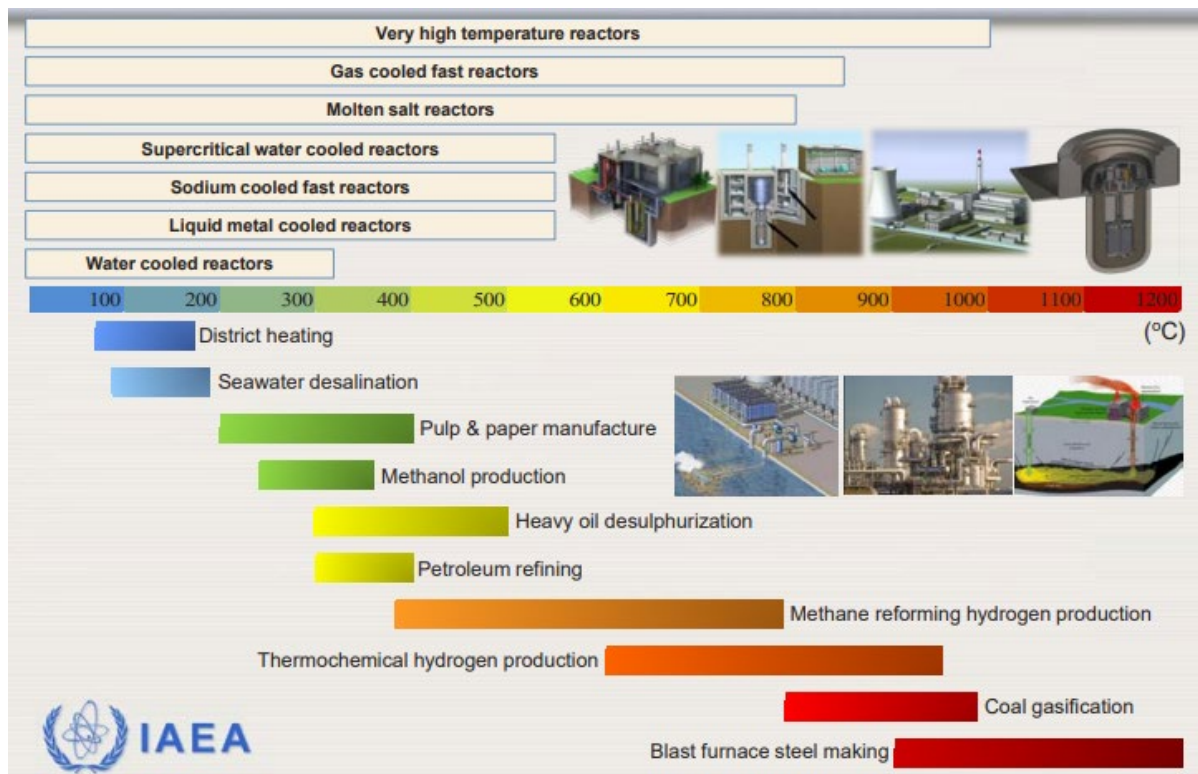


FIG. B.5. SMR designs for non-electrical applications according to system temperature.

26. In November 2021, the Agency held a Technical Meeting on Small Modular Reactor Design for Decommissioning with 31 participants from 20 Member States, which is informing the drafting of a TECDOC entitled *Considerations on Design Aspects of Small Modular Reactors for Decommissioning*

# Nuclear Knowledge Management

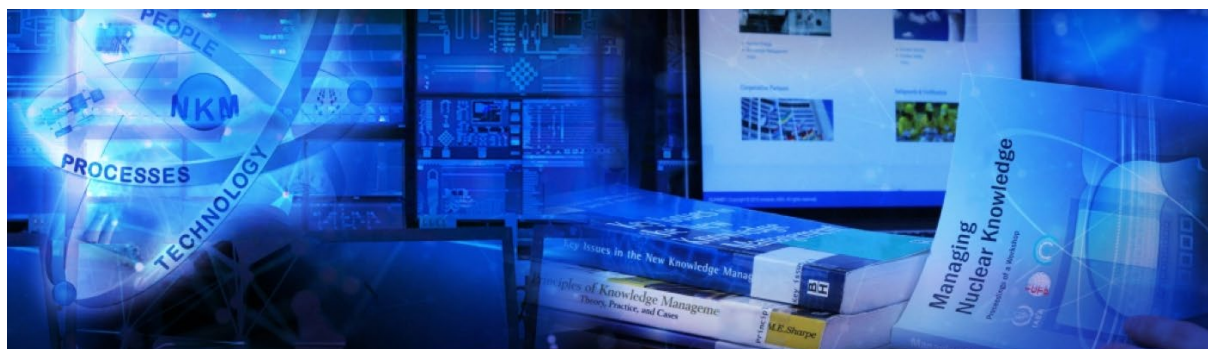
## A. Background

1. In resolution GC(65)/RES/11.C, the General Conference commended the Director General and the Secretariat for their significant, interdepartmental efforts in addressing issues of preservation and enhancement of nuclear knowledge, and encouraged the Director General and the Secretariat to continue to strengthen their current and planned efforts in this area, in a holistic, interdepartmental manner, while consulting and engaging Member States and other relevant international organizations, and to further increase the level of awareness of efforts in managing nuclear knowledge.
2. The General Conference requested the Secretariat to continue to gather, and make available to Member States, nuclear data, information and knowledge resources on the peaceful uses of nuclear energy, including the International Nuclear Information System (INIS) and other valuable databases as well as the IAEA Library and the International Nuclear Library Network (INLN). The General Conference also called on the Secretariat to continue to focus, in particular, on activities aimed at helping interested Member States assess their human resource needs and to identify ways to address those needs, inter alia by encouraging the development of new tools and opportunities to gain practical experience through fellowships.
3. The General Conference also invited the Secretariat, in consultation with Member States, to further develop and disseminate guidance and methodologies for planning, designing, implementing, and evaluating nuclear knowledge management programmes and practices. It also encouraged the Secretariat to continue to facilitate the establishment of effective human resource and knowledge management networks in developing countries, and where appropriate in collaboration with other United Nations organizations and with the support of existing such networks in developed countries.
4. The General Conference requested the Director General to take into account the continuing high level of interest of Member States in the range of issues associated with nuclear knowledge management when preparing and carrying out the Agency's programme.
5. Furthermore, in resolution GC(65)/RES/11.C the General Conference requested the Director General to report on progress in the implementation of resolution GC(65)/RES/11.C to the Board of Governors and to the General Conference at its sixty-sixth (2022) regular session. This Annex has been prepared in response to that request.

## B. Strengthening Nuclear Knowledge Management

6. The Nuclear Knowledge Management Hub (NKMH) went live in 2021 on the IAEA CONNECT platform. The digital platform provides Member States with easy access to the latest information on nuclear knowledge management (NKM) guidance and services to support Member States with operating nuclear facilities and those considering or developing new nuclear programmes. This includes guidance

and methodology documents; an overview of missions, schools and upcoming activities; presentations from past Agency meetings, expert workshops and training events; examples of NKM good practices, shared experiences and lessons learned from nuclear organizations; e-learning courses and training materials; and collaborative development spaces for members of working groups and projects. During the 65th regular session of the General Conference, a side event took place to introduce the NKMH to Member States, attended by 89 participants.



7. The Agency conducted three International Nuclear Management Academy (INMA) missions, including an INMA Initial Assist Visit to the University of West Bohemia in the Czech Republic in November–December 2021, an INMA Initial Assist Visit to the KEPKO International Nuclear Graduate School in the Republic of Korea in March 2022 and an INMA Initial Assist Visit to the University of Idaho in the United States of America in April 2022.

8. A new publication *Mentoring and Coaching for Knowledge Management in Nuclear Organizations* (IAEA-TECDOC-1999), issued in May 2022, captures successful mentoring and coaching practices and approaches being followed by different types of nuclear organizations, including at nuclear power plants (NPPs), technical support organizations, national nuclear organizations and regulatory bodies, and includes case studies from Member State organizations.

## C. Building Capacity and Implementing Nuclear Knowledge Management

9. By the end of June 2022, 2624 participants from 110 Member States had attended the Agency's Nuclear Energy Management (NEM) and NKM Schools.

10. The Russian Federation–IAEA Advanced Nuclear Energy Management School was held in two parts, with a virtual component held in August 2021 and a physical component held in Moscow in October 2021. The event was organized in cooperation with the State Atomic Energy Corporation “Rosatom” through the Rosatom Technical Academy. The event, which had a specialized curriculum, was aimed at middle-level managers and decision makers in the nuclear sector, with a view to enhancing the managerial and technical competencies essential for establishing or expanding national nuclear energy programmes. The School brought together 27 managers and leaders from 15 Member States.

11. As part of the 2021 European Nuclear Young Generation Forum (ENYGF), the first Spain–IAEA Nuclear Energy Management School was held, in cooperation with the Spanish Nuclear Society, in September 2021 (in person). The School was attended by 17 participants from 7 Member States. The synergy with the ENYGF was very successful and created an opportunity for future joint events and activities.



12. The ninth Japan–IAEA NEM School took place virtually in September–October 2021. In cooperation with the Agency, it was organized by the Japan Atomic Energy Agency (JAEA), the Japan Atomic Industrial Forum (JAIF); the JAIF International Cooperation Center; the Japan Nuclear Human Resource Development Network (JN-HRD NET), the National Institute of Technology and the University of Tokyo. The School was aimed at future leaders and managers of nuclear energy programmes in both newcomer countries and those with established programmes. The School brought together 20 participants from 10 Member States.

13. In October 2021, the Agency organized the second Russian Federation–NKM School. This regional School took place in Saint Petersburg, Russian Federation, and was organized by the Agency in cooperation with Rosatom through the Rosatom Technical Academy. This one-week event offered specialized training to professionals who have a role, or may have a role in the near future, in the development or implementation of NKM projects in their organizations. The School was attended by 24 professionals from various nuclear and governmental organizations in 9 Member States.

14. In November 2021, the first Uzbekistan–IAEA NEM School was held. The curriculum and content of the School were adapted to the needs of national participants and the host organization. The School took place in Tashkent and was organized by Uzatom in cooperation with the Agency. The two-week event was intended for young professionals with managerial potential from organizations involved in the national nuclear programme of Uzbekistan. The School was attended by 38 professionals from various institutions in Uzbekistan’s nuclear sector, including relevant ministries, academia, the national regulatory body and the nuclear energy industry.

15. The Agency organized the first European Nuclear Education Network (ENEN)–IAEA NEM School virtually in November 2021. The curriculum and content of the School were adapted to the needs of international participants and the host organization. The two-week event was intended for young professionals with managerial potential from organizations involved in international nuclear programmes with 24 participants from 17 Member States.

16. In December 2021, the first China–IAEA NEM School was held virtually. The curriculum and content of the School were adapted to the needs of the attending participants and the host organization. The two-week event was intended for young professionals involved in their national nuclear programmes. The School was attended by 52 professionals from various institutions in 11 Member States, including academia, national regulatory bodies, relevant ministries and the nuclear energy industry.

17. In April 2022, the first United States of America–IAEA NKM School was held at Texas A&M University, United States of America, with 23 participants from 10 Member States. The School focused on broadening young professionals’ understanding of the basic notions of NKM, in particular strategies and tools such as risk assessment of critical knowledge loss and methodologies for capture and retention of such knowledge.

18. The first Canada–IAEA NEM School was held in Oshawa, Canada, in May 2022, with 21 participants from 9 Member States. The School was conducted in cooperation with the University Network of Excellence in Nuclear Engineering (UNENE), Ontario Tech University and the CANDU Owners Group. The School used the new NEM School framework that includes the core and optional curricula. A visit to the Darlington NPP and a demonstration of NPP simulators were included in the curriculum. The students also focused on four specific areas of nuclear energy through a group project and were mentored by Agency and Canadian experts.

19. In June 2022, the tenth Abdus Salam International Centre for Theoretical Physics (ICTP)–IAEA NEM School took place as a virtual event. This international NEM School has been organized yearly by the Agency in cooperation with the ICTP since 2010. The two-week event focused on broadening young professionals’ understanding of current issues in the nuclear industry, building awareness on recent developments in nuclear energy and sharing international perspectives on issues related to the peaceful use of nuclear technology.

20. In June 2022, the Russian Federation–IAEA Advanced Nuclear Energy Management School was held in Moscow, organized in cooperation with Rosatom through the Rosatom Technical Academy. This one-week event was aimed at supporting middle-level managers and decision makers in the nuclear sector, with a view to enhancing the managerial and technical competencies essential for establishing or expanding national nuclear energy programmes.



*FIG. C.1. “Both academic institutions and the nuclear industry have a role play in ensuring that our education system can produce suitably-qualified and experience nuclear personnel,” said Lerato Makgae, Senior Advisor on Nuclear Stakeholder Management at ESKOM Holdings, during her opening remarks (Photo: DMRE)*

21. The third South Africa–IAEA NEM School took place, in person, in Johannesburg, South Africa, in June 2022. The School was organized by the Agency in cooperation with South African Nuclear Energy Corporation (NECSA), with support from the Department of Mineral Resources and Energy (DMRE). The purpose of the School was to provide an international educational experience for future leaders and managers of nuclear energy programmes in both newcomer countries and those with established programmes from across Africa, funded and implemented by TC. There were 41 participants from 13 Member States.

22. The tenth Japan–IAEA NEM School is scheduled took place in July 2022 in Tokyo. In cooperation with the Agency, it was organized by the JAIF International Cooperation Center, the JAEA, the JAIF, JN-HRD NET, the National Institute of Technology and the University of Tokyo.

23. A regional NKM School for Latin America and the Caribbean is scheduled was held in July 2022. The one-week event, delivered in Spanish, will bring together professionals from across the region, including from Argentina, Brazil, Chile, Paraguay, Peru and Uruguay. The School will include an online training module, conducted on the Latin American Network for Education in Nuclear Technology's (LANENT's) educational platform, to be completed by all participants in preparation for the in-person sessions.

24. The third Russian Federation–IAEA NKM School is scheduled to be held in Saint Petersburg, Russian Federation, in August 2022. It will be organized by the Agency in cooperation with Rosatom through the Rosatom Technical Academy.

25. The Knowledge Management Assist Visit (KMAV) programme continues to provide effective risk management processes and methodologies to ensure that ongoing knowledge management programmes in Member States are maintained in order to support human resource capacity and critical knowledge identification and protection. KMAV missions include the use the Agency's knowledge management maturity self-assessment model, training of experts in Member States and guidance on the preparation of new NKM documents. A total of 14 KMAV missions were conducted to Member States, including to Indonesia in September 2021, to address national-level NKM issues and help in developing a strategic knowledge management programme; a KMAV Level 1 mission in Tashkent, Uzbekistan in November 2021 to help address national-level NKM issues; a Level 3 KMAV mission to the Budapest University of Technology and Economics, Hungary, in December 2021, to address national-level NKM education and training issues; a KMAV Level 2 mission to the Jordan Atomic Energy Commission, Amman, in March 2021, to assess knowledge management maturity and identify gaps; a KMAV Level 1 mission for AFRA-NEST in Port Louis, Mauritius in March–April 2022, to help develop a strategic knowledge management programme; a KMAV Level 1 mission to the College of Sciences and Technology of the University of Rwanda in Kigali in March–April 2022, to address national-level NKM education and training issues; a KMAV Level 2 mission to Santiago de Chile in May 2022, to address national-level NKM issues, assess knowledge management maturity and identify gaps; and a KMAV Level 1 mission to Kenya in May 2022; a KMAV Level 1 mission to Kenya in July 2022; and a KMAV mission for educational providers in Ethiopia, Tunisia and Cameroon in July 2022

26. Additionally another KMAV mission is scheduledfor NPP operators in Mexico in August 2022 to address national-level NKM issues, assess knowledge management maturity and identify gaps.

27. During the reporting period, a number of NKM-related events were held, including a virtual Technical Meeting on Knowledge Management Assist Visit Methodology for Education and Training Providers in July 2021, with 97 participants from 50 Member States; a virtual Technical Meeting on Educational Networks in August 2021, with 64 participants from 31 Member States; a virtual Technical Meeting on Experiences and Lessons Learned for Effective Knowledge Management Programmes in Nuclear Organizations in October 2021, with 42 participants from 28 Member States; a virtual Technical Meeting on Methodology, Practices and Approaches for Determining Critical Knowledge in Nuclear Organizations in November 2021, with 105 participants from 67 nuclear organizations in 39 Member States; and the Annual Meeting of the International Nuclear Management Academy in November 2021, with 40 participants from 21 Member States. Furthermore, the Agency participated in the European Nuclear Society NESTet Conference in Brussels.

## **D. Applying Nuclear Knowledge Management to Development**

28. Human resource development is a priority in Africa. Efforts continued to provide training to skilled mid-level personnel such as engineers and technicians through short- and long-term academic training to build capacities and ensure the availability of skilled staff in African Member States. A core curriculum for radiation, clinical oncology and radiotherapy training schemes in Africa was finalized in 2021. Under project RAF1008, “Supporting Radiation Technologies in Industrial Applications and Preventive Maintenance of Nuclear and Medical Equipment (AFRA)”, a one-month group fellowship training programme on nuclear instrumentation was hosted by the Birine Nuclear Research Centre, Algeria.

29. For Member States in Europe and Central Asia, human resource development remains a priority to maximize the peaceful use of nuclear science and technology. Efforts continued to support the education and training of professionals in nuclear science and technology at various stages in their careers. Through technical cooperation (TC) project CZR0010, “Strengthening Human Resources Capacity, Nuclear Knowledge, Skills Preservation, and Expertise in Relevant Fields of the Peaceful Use of Nuclear Energy”, the Agency arranged training for Czech specialists to ensure the safe, sustainable and reliable operation of institutions and services in the nuclear field. The International School of Nuclear and Radiological Leadership for Safety was held in Athens in November 2021 to train mid-level professionals in safety leadership. The School, supported by TC project RER0043, “Enhancing Capacity Building Activities in the European Nuclear and Radiation Safety Organizations for the Safe Operation of Facilities”, provided the participants with knowledge to enhance their leadership skills in nuclear and radiological safety throughout their careers.

30. In the Asia and the Pacific region, through TC project INS0020, “Supporting Comprehensive Capacity Building of National Nuclear Institutions to Support the Nuclear Industry and Stakeholder Utilization of Nuclear Technology”, more than 280 participants with knowledge management responsibilities from 3 different national organizations and the National Nuclear Energy Agency of Indonesia attended a series of 3 virtual national knowledge management workshops. The workshops provided the participants with knowledge and tools on how to align knowledge management strategies with an organization’s business goals; how to ensure the growth of an organizational culture for knowledge sharing, including practical approaches for tacit knowledge capture; and how to continuously implement proactive knowledge retention and transfer plans to ensure critical knowledge is identified, shared and retained. TC project INS0020 also provided the Polytechnic Institute of Nuclear Technology with support to develop an industry-based curriculum, taking into consideration a goal in Indonesia’s National Medium-Term Development Plan of accelerating and strengthening the link between education and employment by enhancing cooperation between vocational colleges, universities and industry.

31. Efforts to promote the education and training of young professionals in the field of nuclear science and technology continued in the Latin America and the Caribbean region, delivered notably through NUCLEANDO, a new educational programme developed by LANENT with Agency support. NUCLEANDO provides a suite of scholastic tools and resources to help teachers incorporate nuclear science concepts into their curricula. TC project RLA0069, “Promoting Strategic Management and Innovation at National Nuclear Institutions through Cooperation and Partnership Building — Phase II (ARCAL CLXXII)”, continued to support national nuclear institutions in Latin America and the Caribbean to become technically and financially self-reliant.



*FIG. D.1. Brazil's Nuclear and Energy Research Institute (IPEN) routinely provides services to users around the country and throughout the region. For facilities such as IPEN's nuclear research reactor, for instance, delivering radioisotopes and other services to commercial clients and public sector partners in a more effective and efficient way is key for business continuity*

## **E. Applying Nuclear Knowledge Management to Nuclear Safety, Security and Safeguards**

32. The Agency held a virtual Regional Workshop on Nuclear Safety Knowledge Management Programmes in June 2021 for Member States in the Asia and the Pacific region to exchange information, experience and lessons learned in developing nuclear safety knowledge management programmes at both the national and organizational levels.

33. The Agency published *Managing Nuclear Safety Knowledge: National Approaches and Experience* (IAEA Safety Reports Series No. 105), which provides a conceptual basis of nuclear safety knowledge management, suggests key national-level approaches and summarizes experience gained by Member States.

34. The Agency held a virtual Meeting of the Steering Committee on Regulatory Capacity Building and Knowledge Management in December 2021 to exchange information on the current activities of the Secretariat and Member States in managing, developing and strengthening regulatory competence.

35. The Agency held a Regional Workshop on Nuclear Safety Knowledge Management Programmes in Cairo in June 2022 to exchange information, experience and lessons learned in developing nuclear safety knowledge management programmes at both the national and organizational levels.

36. The Agency held a Workshop on Self-assessment of Emergency Arrangements and Use of Emergency Preparedness and Response Information Management System (EPRIMS) in Vienna in April 2022 to provide an overview of the Agency's safety standards in emergency preparedness and response

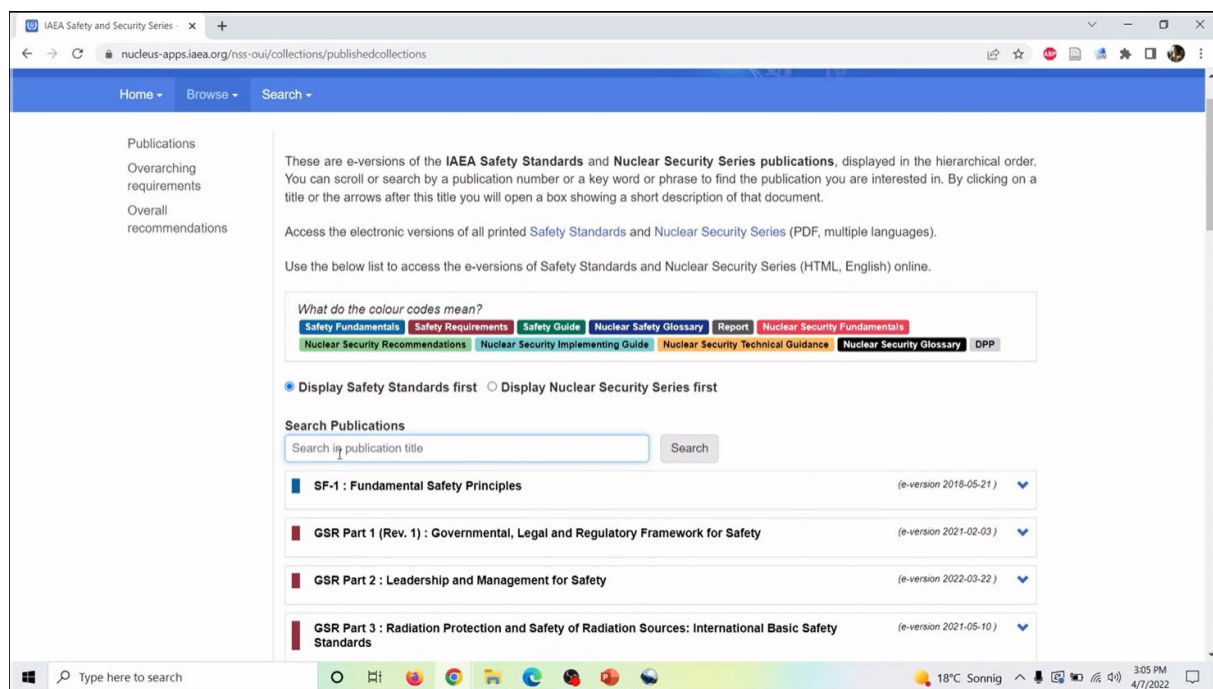


(EPR), highlight the importance of self-assessment against existing safety standards, and present EPRIMS as a tool to support such self-assessment and sharing of information.

37. The Agency signed Practical Arrangements for the establishment of a new capacity building centre (CBC) for EPR with the Institute for Radiological Protection and Nuclear Safety of France in September 2021, and extended its cooperation in EPR with the Korea Institute of Radiological and Medical Sciences, Republic of Korea, in October 2021 and with the Civil Protection School, Austria, in November 2021.

38. International Network for Education and Training for Emergency Preparedness and Response membership grew to 194 in 2022 from 179 in 2021, allowing for the exchange of information and resources and enhancing education and training in EPR through CBCs.

39. The Nuclear Safety and Security Online User Interface (NSS-OUI) provides users with easy access to the content of Agency publications on nuclear safety and security, namely IAEA Safety Standards and Nuclear Security Series publications. It facilitates direct access to the content of the publications and navigation between them and enables authorized users to provide feedback on the publications. Between September 2021 and April 2022 several improvements to the navigation functionality and user friendliness were implemented. The content of all IAEA Safety Standards and Nuclear Security Series publications issued, were added to the NSS-OUI. References to relevant newly issued informational publications were inserted.



*FIG. E.1. Demonstration of Nuclear Safety and Security Online User Interface*

40. During the reporting period, the Agency conducted two International Schools on Nuclear Security virtually, in Arabic in November 2021 and in English in April 2022; one Regional School on Nuclear Security for the Asia and the Pacific region virtually in November 2021; three International Schools on Nuclear Security for participants in the Marie Skłodowska-Curie Fellowship Programme in English in



a hybrid format in November and December 2021, and another is planned for August 2022; and one National School on Nuclear Security in Portuguese in person in June 2022.



*FIG. E.2. Fellows of the Marie Skłodowska-Curie Fellowship Programme at the International School on Nuclear Security*

41. An international seminar on the Amendment to the Convention on the Physical Protection of Nuclear Material was conducted for participants in the Marie Skłodowska-Curie Fellowship Programme in November–December 2021 in Vienna.
42. The Agency finalized the curriculum for a pilot international master’s degree programme in 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, Russian Federation, in September 2021.
43. The Agency held the International School of Nuclear and Radiological Leadership for Safety in Athens in November 2021 to train early to mid-career professionals in nuclear and radiological leadership for safety. Additionally, the Agency, in cooperation with Tokai University, Japan, held a virtual School on this topic in February–March 2022.
44. The Agency developed the External Events Safety Section (EESS) Portal for sharing and strengthening nuclear site and design safety-related knowledge.
45. The Agency developed a database on Site and External Events Design (SEED) mission reports and the related Tool for SEED Mission Assessment (TOSMA), an artificial intelligence-based dashboard for efficient and effective knowledge management of the missions’ statistics, and safety issues identified during SEED missions over the past decades.

46. In 2021, the Agency began to implement the IAEA Comprehensive Capacity-Building Initiative for SSACs and SRAs (COMPASS) in all seven States that had joined the initiative for its two-year pilot phase. COMPASS was launched in 2020 to further support efforts to strengthen and sustain the effectiveness of State or regional authorities responsible for safeguards implementation (SRAs) and State systems of accounting for and control of nuclear material (SSACs). A wide range of activities were conducted with the pilot States during the reporting period, including the organization of outreach events and training courses, the provision of legislative and regulatory assistance and the procurement of safeguards-related equipment and information technology hardware. Additionally, the Agency partnered with other Member States to help COMPASS States establish or strengthen their respective processes and procedures to support safeguards implementation. Such peer-to-peer support includes expert assistance towards the development of national safeguards training programmes so that pilot States can develop and maintain the basic knowledge and capabilities required to implement safeguards.

47. Through its Safeguards Traineeship Programme for young graduates and junior professionals, the Agency provides knowledge and technical skills to young trainees in implementing safeguards. During 2021 and 2022, nine trainees participated in the Programme, including five women.

48. The Agency held three one-day workshops on knowledge management to improve the integration of knowledge management practices into the daily work of the Department of Safeguards. These interactive workshops provided a forum to review how an integrated approach to NKM can benefit the safeguards workforce.

49. The Agency continued to expand the State Declarations Portal (SDP), a web-based system that supports secure bi-directional information exchange between the Agency and SRAs. The SDP allows States to submit a wide variety of communications, including safeguards reports and declarations. By keeping a log of communication exchanges between the Agency and SRAs, the SDP also strengthens institutional memory.

## **F. Strengthening Networks Related to Nuclear Education and Training**

50. The International Network for Nuclear Security Training and Support Centres annual meeting was held in July 2022 to advance the work of this collaborative network of training and support institutions that are involved in the provision of nuclear security training or technical and scientific support services.

51. The International Nuclear Security Education Network annual meeting was held virtually in August 2021, gathering over 100 participants from 41 States, at which nuclear security education activities and the impact of COVID-19 were discussed.

52. The Agency provides support to LANENT through project RLA0065, “Furthering Knowledge Management Implementation in Nuclear Organizations and Strengthening Nuclear Education”. The project has made an essential contribution to preserving, promoting and sharing nuclear knowledge, as well as fostering nuclear knowledge transfer in the Latin America region in areas such as education, health, industry, agriculture, government, the environment and mining. LANENT also seeks to communicate the benefits of nuclear technology to the public, with the aim of stimulating interest in nuclear technology in younger generations. A dedicated NUCLEANDO website has been created.

53. Under TC project RAS0075, “Networking for Nuclear Education, Training, and Outreach Programmes in Nuclear Science and Technology in the Framework of ANENT (Asian Network for

Education in Nuclear Technology)”, a web portal has been developed consisting of a learning management system and a learning object repository. The portal’s resources help in capacity building and human resource development in the Asia and the Pacific region, particularly for developing countries and countries with limited access to high-quality educational resources in nuclear science and technology. Monthly teleconference meetings of ANENT were conducted with the aim of increasing the educational resources for the network and its utilization. TC project RAS0091, “Supporting Nuclear Science and Technology Education at the Secondary and Tertiary Level”, launched in 2022, expands the scope of collaboration to all partners from the nuclear science and technology educational network at the secondary and tertiary levels in the Asia and the Pacific region.

54. The Agency provides support to AFRA-NEST through the TC project RAF0059, “Supporting the Establishment of the Nuclear Education Science and Technology Network”. The main objective of AFRA-NEST is to facilitate operation and networking in higher education, training and related research in nuclear science in the Africa region. The results of the first survey conducted for AFRA-NEST were published in 2021. The survey aimed to evaluate the situation as well as specific needs and requirements for providing e-learning materials and platforms, and to further understand people’s experiences with e-learning, their preferences concerning topics, platform features and learning habits

55. In March 2022, representatives of ANENT, LANENT, AFRA-NEST, ENEN, UNENE and the Regional Network for Education and Training in Nuclear Technology were part of the international jury of the Agency’s International Student Video Contest on the role of nuclear technology in addressing climate change, in which more than 1000 students from 34 Member States participated.

56. In November 2021, regional educational networks were presented at the virtual Nuclear Science and Technology Education Exhibition under TC project RAS0079, “Educating Secondary Students and Science Teachers on Nuclear Science and Technology”, and shared their innovative visions for development using nuclear science and technology, including support for adaptation to climate change and other issues of global concern.



*FIG. F.1. Hua Liu, Deputy Director General and Head of the Department of Technical Cooperation addresses participants at the virtual Nuclear Science and Technology Education Exhibition in November 2021*

57. The Agency contributed to the ENEN master's programme on nuclear safeguards through the design, development and implementation of sessions on Agency safeguards-related topics. This programme provides an opportunity to develop specific competencies and train personnel in the field of safeguards in order to support the continuous development of a professional, competent and motivated workforce.

58. The IAEA CONNECT platform is an easy-to-use online environment to facilitate the sharing of information and capacity building while offering a centralized resource hub in topical areas. The IAEA CONNECT platform has established itself as the place to bring together professionals and experts from the Secretariat and Member States, serving more than 7700 members from over 20 topical networks. Two new networks are scheduled to join in 2022: the International Target Values Network and the International Network of Life Management of Nuclear Power Plants.

59. The IAEA CONNECT platform is currently undergoing upgrades to the underlying technology and a redesign to improve usability. In 2022, the structure of the Nuclear Wiki will be simplified to allow article submissions on a wider variety of topical areas and from a greater number of technical experts. The Nuclear Wiki is available to IAEA CONNECT users, and contains technical articles developed and maintained by the Secretariat with the support of international experts.

60. As a fundamental element of the Agency's strategic approaches to education and training, the Cyber Learning Platform for Network Education and Training (CLP4NET) experienced significant growth during this reporting period as the Agency's standard delivery mechanism for e-learning. By the end of April 2022, registered users to CLP4NET increased to over 60 000, and the number of courses increased to 715. In addition to e-learning courses, the Agency has started to offer webinars through CLP4NET. As of now, 142 webinars have been made available on CLP4NET, with many more expected in the coming years.

61. A personalized dashboard showing course progress, upcoming courses, calendar, timeline and recently visited courses (among other functionalities) will soon be made available on CLP4NET. A learning resources catalogue has been launched on the Agency's website, which serves to increase the visibility and accessibility of the e-learning offerings available to Member States, and will be the central access point for all Agency webinars. A new Agency e-learning governance framework to improve quality and optimize resources while developing e-learning materials and products and to control the life cycle of those outputs is close to implementation Agency-wide. This new governance framework will help to ensure better control of e-learning projects and products and to maintain a high level of quality in the e-learning resources offered to Member States.

62. In order to ensure that Member States have continuous access to basic safeguards knowledge, the Agency's updated CLP4NET is now used as the primary learning management system for all Agency safeguards training aimed at Member States. During the reporting period, the Agency continued to develop safeguards e-learning courses for Member States, with new topics such as design information verification, the State Declarations Portal and Protocol Reporter 3. Furthermore, the Agency launched a Safeguards Webinar Series, available on CLP4NET, exploring a variety of safeguards implementation topics drawing on both internal and international experience.

63. The INLN membership increased to 63 members from 43 Member States. Members communicate with each other directly and efficiently through the INLN Forum on NUCLEUS. The IAEA Library held a virtual meeting of the INLN, with 19 participants during 2 sessions, where ideas for improved resource sharing and communication were discussed.

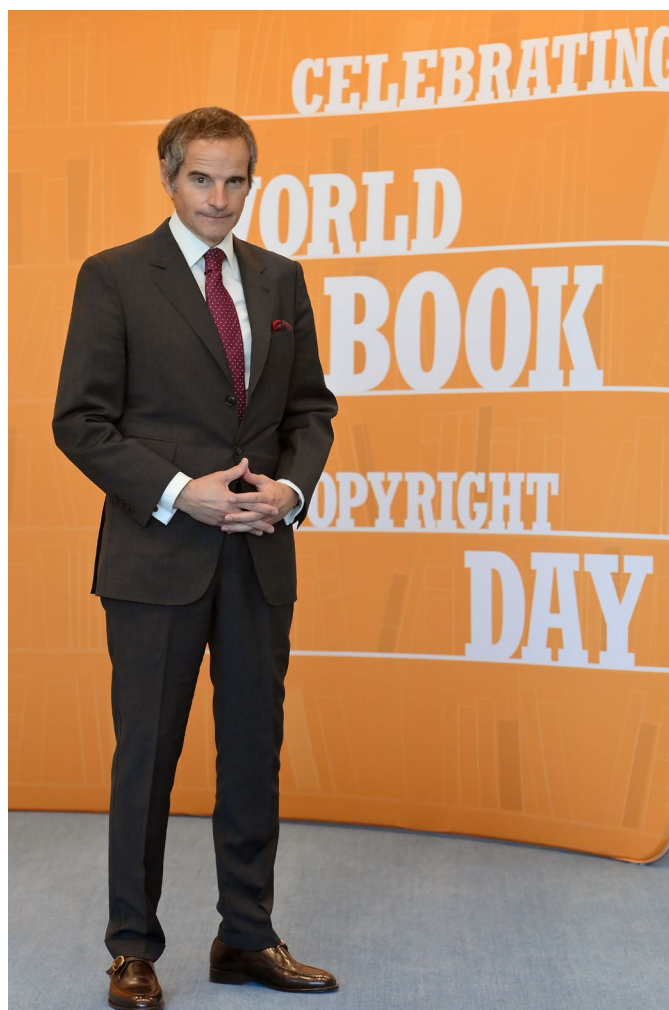
## **G. Nuclear Information**

64. INIS continues to be maintained and expanded as a repository of information on the peaceful uses of nuclear energy. Over 100 000 high-quality metadata records are acquired every year — reaching a total number of over 4.5 million. The information is indexed and made freely available to Member States through the INIS Repository, which reaches over 2.4 million users yearly. An 18-year project to digitize INIS microfiche was completed, comprising in total over 18 million microfiche frames. Major improvements in technical capacity included increasing usage of automation along with artificial intelligence. The INIS Thesaurus, a ‘knowledge organization system’ containing over 31 000 descriptors, has been further enriched with new relevant terms, taking into account input from Member States and the INIS Thesaurus Advisory Group. INIS completed special preservation projects, including those related to Chernobyl, while a project involving the High Temperature Materials Laboratory at the Jülich Research Centre in Germany is ongoing, and a project involving legacy Agency publications and conferences has commenced.

65. The IAEA Preprint Repository was developed to speed up the time it takes Agency publications to reach the public. The repository uses the INIS process and infrastructure, and all items placed on the preprint server are made available simultaneously in the INIS Repository. It was officially launched in January 2022 and currently contains over 75 preprints.

66. Since the reinstatement of the Memorandum of Agreement between the IAEA and the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA) for the distribution of OECD/NEA Data Bank nuclear computer codes and processed nuclear data libraries to eligible IAEA Member States, 37 OECD/NEA Data Bank liaison officers have been delegated to as many IAEA institutions in 17 IAEA Member States.





*FIG. G.1. The Director General visits the IAEA Library on the occasion of World Book and Copyright Day 2022*

67. The IAEA Library continued to provide access to nuclear information by connecting users to all available information resources, in both print (100 000+ items) and electronic (83 000+ electronic journal titles and 68 databases) formats. Users borrowed over 2 350 books and accessed the electronic resources over 350 000 times. The IAEA Library also provided users with access to 684 items not available in the collection through interlibrary loan, document delivery and article delivery services. The library held 14 training sessions, reaching a total of 251 participants in person and virtually. The Agency held the sixth annual World Book and Copyright Day event online, in collaboration with the libraries of other Vienna International Centre based organizations. The event included 10 virtual sessions over 4 days, for which 295 individuals registered.